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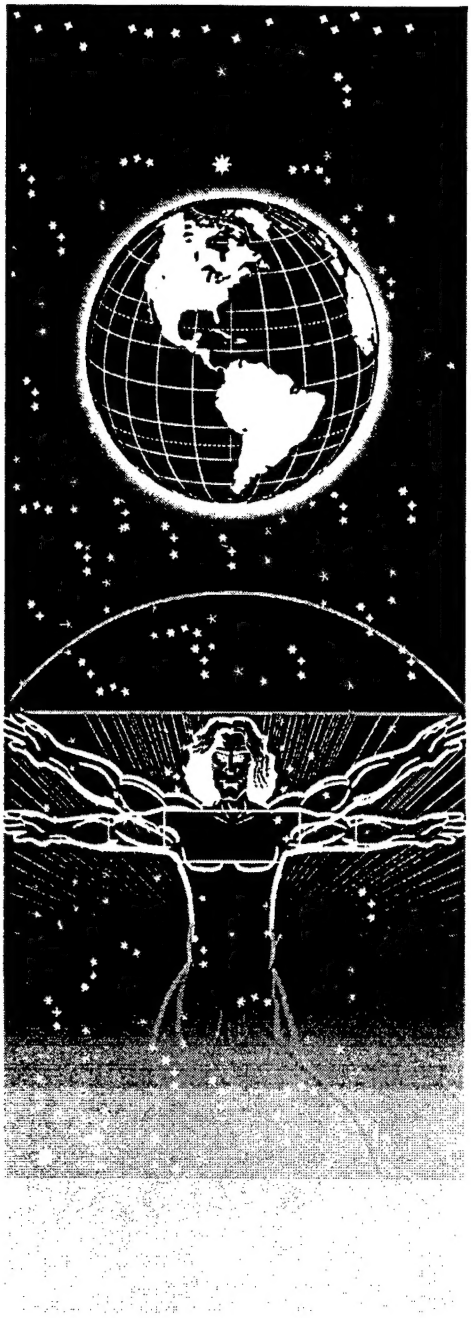

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Aircraft Engine and Auxiliary Power Unit Emissions Testing: Vol. 1, Executive Summary

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March 1999

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This report is the product of a 2-year emissions testing program designed to document, characterize, and evaluate emissions from sixteen aircraft engines, two helicopter engines, and two auxiliary power units (APUs) burning JP-8 fuel. The purpose of this engine testing program was to develop emission factors for the tested engines under representative engine load conditions. All testing was performed by the Environmental Quality Management Inc. (EQ) and Roy F. Weston, Inc. (Weston) team. Testing was conducted for criteria pollutants and select hazardous air pollutants (HAPs), e.g., aldehyde/ketones and semivolatile and volatile organic compounds.

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EXECUTIVE SUMMARY

1.0 INTRODUCTION

In 1973, the Defense Energy Task Force recommended the standardization of fuels used by the U.S. Department of Defense (DOD). The Joint Logistics Coordinating Group, established to perform the standardization studies, recommended that the U.S. Air Force (USAF) replace naphtha-based JP-4 (MIL-T-5624), with the kerosene-based JP-8 (MIL-T-83133), as the standard turbine fuel.

Although engine emissions of criteria pollutants[1] from combustion of JP-4 are well documented, little information existed for criteria pollutants and hazardous air pollutants (HAPs)[2] from combustion of JP-8 fuel. Consequently, the need to document emissions from engines burning JP-8 was identified. This report is the product of a 2-year emissions testing program designed to document, characterize, and evaluate the emissions from sixteen aircraft engines, two helicopter engines, and two auxiliary power units (APUs) burning JP-8 fuel.

1.1 OBJECTIVES

The purpose of this engine emissions testing program was to develop emission factors for the tested engines under representative engine load conditions. All testing was performed by the Environmental Quality Management Inc. (EQ) and Roy F. Weston, Inc. (Weston) team. Testing was conducted for criteria pollutants and select

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1 Criteria pollutants are pollutants for which National Ambient Air Quality Standards (NAAQS) (see 40 CFR 50) have been established. They include carbon monoxide, nitrogen dioxide, sulfur dioxide, particulate matter, lead, and ozone (and its precursors).

2 Hazardous air pollutants (HAPs) are toxic chemicals and compounds regulated under Title III, Section 112(b) of the Clean Air Act Amendments of 1990 (CAAA). Presently, there are 189 HAPs.

hazardous air pollutants (HAPs), e.g., aldehyde/ketones and semivolatile and volatile organic compounds.

Table 1 is a summary of the tested engines and test locations.

Table 1. Test Engines and Locations

Location	Engine Designation	Aircraft or APU	Test Dates
Kelly AFB, TX	T56-A-7 TF39-GE-1C GTCP85-180 GTCP165-1	C-130 C-5A/B C-130H (APU) C-5A/B (APU)	6 – 29 Jan. 1997
Corpus Christi Army Depot	T700-GE-700	UH60A, UH60G (helicopter)	3 – 11 Mar. 1997
Tinker AFB, OK	F110-GE-100 F101-GE-102 TF33-P-102 F108-CF-100 TF33-P-7/7A	F-16 C/D/N B-1B C/EC/RC-135E KC-135R C141	14 Apr. 1997 - 2 May 1997
Laughlin AFB, TX	J69-T-25 J85-GE-5A	T-37 T-38	12 – 20 Mar. 1997
Charleston AFB, SC	F117-PW-100	C-17	15 – 16 Oct. 1997
Edwards AFB, CA	F118-GE-100 F404-GE-F1D2/400 F110-GE-129 F100-PW-100 F100-PW-229	B-2 F-117A and F/A-18C/D F-16C/D F-15 F-15 and F-16	17 – 19 Nov. 1997 & 3 – 5 Dec. 1997
Naval Aviation Depot, Cherry Point, NC	T64-GE-100	MH53J (helicopter)	27 – 29 Jan. 1998
Barnes Air National Guard Base, MA	TF34-GE-100A	A-10	9 – 12 Feb. 1998

2.0 EMISSION TESTING SCHEDULE

The field test program began at Kelly AFB on 6 January 1997 and was completed at Barnes Air National Guard Base on 12 February 1998. The test windows were selected to allow base personnel to target exact test dates based on the availability of engines, test facilities, and operating personnel. The test schedule was as

follows: Kelly AFB testing was conducted between 6 and 27 January 1997; Corpus Christi Army Depot testing was conducted between 3 and 11 March 1997; Laughlin AFB testing was conducted between 12 and 20 March 1997; Tinker AFB testing was conducted between 14 April and 2 May 1997; Charleston AFB testing was conducted on 15 and 16 October 1997; Edwards AFB testing was conducted 17 through 19 November 1997, and 3 through 5 December 1997; continuous emission monitoring testing for gaseous pollutants only at Edwards AFB was conducted between 6 and 8 January 1998; Naval Aviation Depot Cherry Point testing was conducted between 27 and 29 January 1998; and Barnes Air National Guard Base testing was conducted between 9 and 12 February 1998.

3.0 SAMPLING METHODOLOGY

Sampling was performed for criteria pollutants and those HAPs that are products of incomplete combustion (PICs). Environmental Protection Agency (EPA) emissions test methods (Title 40, Code of Federal Regulations, Part 60, Appendix A) were followed during this test program. The test methods were modified where necessary due to the unique circumstances encountered during the program: i.e., high flow rates, unique exhaust stack configurations, and large volumes of dilution (ambient) air in the exhaust gas stream. A custom EPA Method 5 was used at several locations due to the physical configuration of the test cell. The nature of these locations did not permit a full cross-section traverse; instead, single point sampling was performed. A verification was made through the use of tracer gas that the sample point was representative of the entire exhaust stream. The following is a list of the constituents of the exhaust stream that were measured along with the corresponding EPA test methods used:

- Filterable and condensable particulate (EPA Methods 5 and 202).
- Aldehydes and ketones (EPA 0011[3] and TO-05).

[3] From EPA SW-846.

- Semivolatiles (EPA Method 0010).
- Volatile organic compounds (VOCs) (EPA Method 0030).
- Oxygen and carbon dioxide (EPA Method 3A).
- Carbon monoxide (EPA Method 10).
- Nitrogen oxides (EPA Method 7E).
- Total hydrocarbons (THCs) (EPA Method 25A).

Sampling was not performed for sulfur dioxide and metals in the engine exhaust streams. Historic testing of metals provided random results with a number of interferences. Sulfur dioxide emissions were reported based on the procedure documented by AESO. This procedure estimates that sulfur dioxide emissions can be estimated by assuming all sulfur in the fuel undergoes complete oxidation to SO_2. The sulfur content in JP-8 fuel was determined during testing to assure consistency with published results. The emission factor for SO_2 is provided in this report. JP-8 fuel samples were also collected for metal analysis. The following compounds were not detected above the method detection limit when the fuel samples were analyzed: antimony, arsenic, barium, beryllium, cadmium, cobalt, chromium, copper, lead, manganese, mercury, nickel, phosphorus, selenium, silver, thallium, and zinc. Therefore, the mass emission rate of metals was not calculated. Dioxins/furans and other HAPs not listed in Volume 2 would not have been emitted in significant quantities to be readily detected by conventional sampling methods. Therefore, these compounds were not part of the emissions testing program.

The exhaust flowrate was measured directly using EPA methods at the APU test cells (Kelly AFB), Corpus Christi Army Depot engine test cell, and the engine test facility at the Naval Aviation Depot, Cherry Point. The volume of exhaust gas for the jet engine test cells at Kelly AFB, Laughlin AFB, Tinker AFB, Charleston AFB, Edwards AFB, and Barnes ANGB was not measured directly but was calculated through the use of a tracer gas methodology and calculated by carbon balance.

Ambient air samples were collected and analyzed to permit correction for background conditions and thus reduce any potential bias. Ambient air samples were

analyzed for many of the same compounds found in the exhaust stream. Volume 2 provides a comparison of emissions test method detection limits, ambient air test method detection limits, and actual observed maximum ambient concentrations for those pollutants. Ambient air samples were collected concurrent with emissions testing to account for emissions from large nearby sources (e.g., exhaust from other test cells) having the potential to bias the test results.

Ambient samples were collected inside each of the test cells and analyzed for the following compounds:

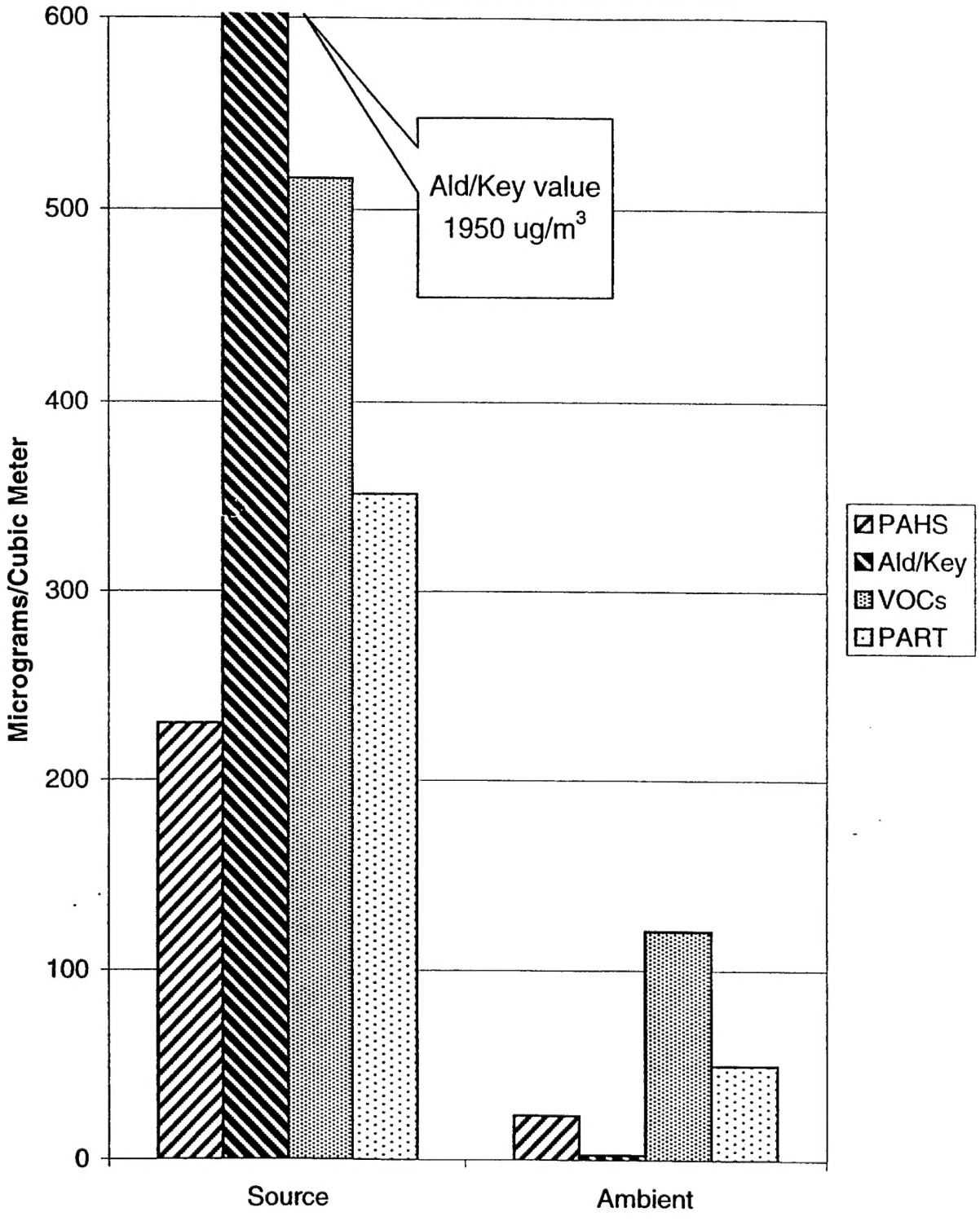
- Particulate - TSP (40 CFR, Part 60, Appendix B).
- Aldehydes and ketones (EPA Method TO-5, Weston modification).
- Semivolatiles (EPA Method TO-13).
- VOCs (EPA Method TO-14).

During the sampling program, ambient pollutant concentrations were subtracted from source concentrations to account for background levels. During the program, background concentrations of pollutants were generally in the <1 to 20 percent range when compared to source concentrations. Background concentrations were highly dependent on local background sources and entrainment/re-entrainment of test cell exhaust. Figure 1 provides a general illustration of source vs. ambient pollutant concentrations. The results presented are the sum of detected compounds for each chemical group for the TF39-GE-1C engine. The ambient air concentration determined at Kelly AFB are representative of typical ambient concentrations noted during the test program.

3.1 ENGINE TESTING CONSIDERATIONS/COMPLICATIONS

Emissions testing was performed on a series of engines at standard power settings. Aircraft engines were tested at three to five actual flight settings, depending on

Figure 1. Source Vs. Ambient Concentration Comparison Pollutant Concentrations TF39-GE-1C Idle



the engine type. Table 2 summarizes the power settings sampled for each engine. Nominal engine conditions for emissions sampling are provided below:

- Idle (I)
- Approach (A)
- Intermediate (N)
- Military (M)
- Afterburner (AB) (Between Zone 1 and Zone 3)

Table 2. Engine Power Settings Sampled

ENGINE	POWER SETTINGS SAMPLED
T56-A-7	I, A, N, M
TF39-GE-1C	I, A, N, M
GTCP85-180	Single constant setting
GTCP165-1	Single constant setting
T700-GE-700	See paragraph below
F110-GE-100	I, A, N, M, AB (Zone 1)
F101-GE-102	I, A, N, M, AB (Zone 1)
TF33-P-102	I, A, N, M
F108-CF-100	I, A, N, M
TF33-P-7/7A	I, A, N, M
J69-T-25	I, A, N, M
J85-GE-5A	I, A, N, M
F117-PW-100	I, A, N, M
F118-GE-100	I, A, N, M
F404-GE-F1D2/400	I, A, N, M, AB (Zone 3)
F110-GE-129	I, A, N, M, AB (Zone 1)
F100-PW-100	I, A, N, M, AB (Zone 1)
F100-PW-229	I, A, N, M, AB (Zone 1)
T64-GE-100	See paragraph below
TF34-GE-100A	I, A, N, M

Auxiliary Power Units (APUs) were tested at one power setting. Each of the helicopter engines (i.e., T700-GE-700 and T64-GE-100) was tested at four power settings. The T700-GE-700 was tested at ground idle, flight idle, flight maximum, and

overspeed, while the T64-GE-100 helicopter engine was tested at ground idle, 75% normal, normal, and military.

Emissions tests comprised three 1-hour sampling runs for each pollutant at each power setting with the exception of semivolatiles and aldehydes/ketones tests. Due to sample volume requirements needed to meet method detection limits, semivolatiles and aldehydes/ketones were collected over a 3-hour sampling period. Certain engines (F101-GE-102, F110-GE-100, T700-GE-700, T56-A-7, TF39-GE-1C, J69-T-25, and J85-GE-5A) could not be operated continuously at maximum power (military, afterburner, or overspeed) for one continuous hour in order to prevent engine and/or test cell damage. Sample run times in these operative modes were reduced to a "safe" operating period. The sample collection procedures were reduced to accommodate the reduced operating time. In order to reach the analytical detection limit for the target pollutants, the sample team paused the sample run at the end of the safe operating period, waited as the engine was allowed to cool, then resumed sampling for the next operating period until the 1-hour sample run was completed. The semivolatile and the aldehyde and ketone samples were collected over the three 1-hour runs (yielding a 3-hour sample period) for that power setting to obtain a minimum sample volume that provides appropriate detection limits. The F117-PW-100 could not be operated for a reasonable amount of time at the military setting. Therefore, no testing was conducted at this setting.

4.0 RESULTS

4.1 GASEOUS POLLUTANTS

Results of the gaseous emissions testing are presented in Table 3. The tables present both emission rates and factors for NO_x, CO, THC, and CO_2 for each engine at each engine test condition. The emissions presented are the average of three 1-hour sampling runs. Results of individual runs are presented in Volume 2 of this report.

Table 3. Engine Emission Summary for Criteria Pollutants

Engine/Condition	Nitrogen Oxides NO_x as NO_2		Carbon Monoxide CO		Total Hydrocarbons THC as CH_4		Carbon Dioxide CO_2	
	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel
T56-A-7								
Idle	5.48	7.58	3.66	5.05	2.60	3.59	2120	2930
Approach	6.64	7.54	3.42	3.89	0.79	0.90	2640	3000
Intermediate	15.93	9.14	3.37	1.93	1.14	0.65	3961	2272
Military	28.19	12.48	5.20	2.31	1.00	0.44	6296	2775
TF39-GE-1C								
Idle	4.89	3.36	84.63	58.21	23.90	16.43	4406	3030
Approach	260.95	24.72	8.10	0.77	6.96	0.67	33345	3159
Intermediate	353.18	28.16	19.17	1.53	ND	ND	39617	3159
Military	452.79	32.66	17.81	1.28	ND	ND	43814	3161
GTCP85-180								
Constant	1.28	4.73	2.04	7.57	0.01	0.05	906	3353
GTCP165-1								
Constant	1.22	4.52	3.76	13.93	0.07	0.24	909	3374
J69-25								
Idle	0.13	0.80	26.73	159.84	2.51	15.00	539	3224
Intermediate	2.55	2.92	33.37	38.25	0.06	0.07	2480	2842
Military	4.91	4.52	35.65	32.85	0.21	0.20	3443	3173
J85-5A								
Idle	0.58	1.14	108.59	211.97	17.43	34.02	1400	2732
Intermediate	1.39	1.74	98.82	123.43	4.53	5.66	2365	2953
Military	7.24	2.92	90.18	36.40	1.45	0.58	7696	3106
Afterburner	16.10	2.09	109.51	14.19	17.65	2.29	24148	3129
T700-GE-700								
Ground Idle	0.45	3.35	6.19	46.22	NA	NA	512	3823
Flight Idle	5.14	10.95	2.40	5.12	0.10	0.22	1693	3609
Flight Max	7.43	11.88	2.20	3.51	0.35	0.56	2386	3813
Overspeed	8.28	11.42	2.04	2.81	0.38	0.53	2243	3092

NA - Hydrocarbon Analyzer down during run.

ND - Value represents the method detection limit. Compound may be present at a value less than the detection limit.

Table 3 (continued)

Engine/Condition	Nitrogen Oxides NO_x as NO_2		Carbon Monoxide CO		Total Hydrocarbons THC as CH_4		Carbon Dioxide CO_2	
	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel
TF33-P-102								
Idle	1.55	1.39	105.85	95.06	101.21	90.91	2580	2317
Approach	30.16	6.37	24.81	5.24	6.51	1.37	15442	3259
Intermediate	45.56	7.88	12.21	2.11	8.67	1.50	15274	2642
Military	91.35	12.08	0.00	0.00	4.19	0.55	25883	3423
TF33-P-7/7A								
Idle	0.87	0.80	147.51	134.91	152.39	139.27	2825	2583
Approach	34.77	7.13	47.25	9.69	24.95	5.14	15346	3145
Intermediate	51.48	8.10	26.45	4.16	3.50	0.55	20148	3170
Military	85.05	10.29	12.33	1.49	ND	ND	26249	3176
F108-CF-100								
Idle	4.41	3.88	26.87	23.65	ND	ND	2694	2371
Approach	14.59	5.73	21.84	8.57	ND	ND	6624	2600
Intermediate	62.36	11.04	13.09	2.32	ND	ND	16257	2877
Military	77.83	12.05	2.30	0.36	3.88	0.60	18377	2846
F101-GE-102								
Idle	4.58	4.10	27.32	24.47	ND	ND	4158	3723
Approach	41.51	9.16	4.65	1.03	2.09	0.46	13284	2932
Intermediate	86.22	13.15	5.58	0.85	2.60	0.40	19152	2921
Military	100.43	12.83	6.50	0.83	2.91	0.37	27424	3503
Afterburner	259.11	16.91	665.98	43.47	947.21	61.82	45596	2976
F110-GE-100								
Idle	4.18	3.77	26.79	24.16	1.14	1.03	4211	3797
Approach	49.69	9.78	29.33	5.78	1.30	0.26	14353	2826
Intermediate	124.02	16.84	25.42	3.46	2.04	0.28	23602	3204
Military	329.41	29.02	38.39	3.38	1.89	0.17	35794	3153
Afterburner	257.94	14.25	1,219.25	67.27	459.02	25.33	46608	2574

ND - Value represents the method detection limit. Compound may be present at a value less than the detection limit.

Table 3 (continued)

Engine/Condition	Nitrogen Oxides NO_x as NO_2		Carbon Monoxide CO		Total Hydrocarbons THC as CH_4		Carbon Dioxide CO_2	
	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel
F117-PW-100								
Idle	3.68	3.72	22.20	22.43	2.03	2.05	3790	3828
Approach	71.94	15.47	2.36	0.51	2.01	0.43	21500	4624
Intermediate	340.51	32.74	3.32	0.32	4.02	0.39	45246	4351
F118-GE-100								
Idle	4.72	4.30	23.02	20.98	0.65	0.59	3363	3066
Approach	41.85	11.09	7.62	2.02	3.28	0.87	10424	2763
Intermediate	114.38	18.01	5.36	0.84	ND	ND	23314	3671
Military	360.59	33.12	7.07	0.65	ND	ND	40854	3752
F404-GE-F1D2/400								
Idle	1.17	1.71	75.47	110.51	35.14	51.46	2305	3380
Approach	24.46	7.86	6.27	2.02	3.76	1.21	10005	3216
Intermediate	110.10	17.04	9.94	1.54	1.18	0.18	22005	3405
Military	199.91	25.83	11.47	1.48	0.91	0.12	31147	4025
Afterburner	86.05	5.43	797.48	50.29	425.55	26.83	50992	3216
F110-GE-129								
Idle	2.52	2.62	43.28	45.01	4.09	4.25	4823	5016
Approach	64.84	13.42	9.34	1.93	ND	ND	26676	5522
Intermediate	123.67	17.82	10.61	1.53	ND	ND	31757	4577
Military	175.13	25.24	10.11	1.46	7.00	1.01	31757	4577
Afterburner	110.39	15.91	984.82	141.93	723.51	104.27	39697	5721
F100-PW-100								
Idle	4.40	4.12	22.41	21.00	3.60	3.37	3828	3587
Approach	33.13	12.15	8.18	3.00	0.52	0.19	9186	3370
Intermediate	261.83	34.69	8.27	1.10	ND	ND	28870	3825
Military	331.25	43.88	8.27	1.10	2.78	0.37	28870	3825
Afterburner	279.19	36.98	262.30	34.75	48.41	6.41	36088	4781

ND - Value represents the method detection limit. Compound may be present at a value less than the detection limit.

Table 3 (continued)

Engine/Condition	Nitrogen Oxides NO_x as NO_2		Carbon Monoxide CO		Total Hydrocarbons THC as CH_4		Carbon Dioxide CO_2	
	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel	lbs/hr	lbs/1,000 lbs fuel
F100-PW-229								
Idle	4.13	3.80	11.05	10.16	0.42	0.38	2823	2597
Approach	46.71	15.08	3.62	1.17	0.65	0.21	13142	4242
Intermediate	102.37	17.53	0.85	0.15	1.74	0.30	20120	3446
Military	336.55	57.65	3.84	0.66	3.14	0.54	26826	4595
Afterburner	297.28	50.92	447.33	76.62	94.95	16.26	46946	8042
T64-GE-100								
Ground Idle	0.33	1.11	22.79	76.60	8.24	27.70	995	3346
75% Normal	6.44	6.84	7.39	7.85	0.21	0.23	3212	3413
Normal	16.06	9.46	3.75	2.21	0.05	0.03	5109	3009
Military	20.87	11.29	4.01	2.17	0.05	0.03	5998	3245
TF34-GE-100A								
Idle	0.16	0.33	32.68	66.46	7.95	16.17	946	1926
Approach	2.89	3.09	26.05	27.93	0.47	0.51	2771	2970
Intermediate	8.49	5.61	13.43	8.88	0.61	0.40	3756	2484
Military	23.94	9.11	10.35	3.94	1.56	0.70	12786	4865

ND - Value represents the method detection limit. Compound may be present at a value less than the detection limit.

4.2 PARTICULATE EMISSIONS

Particulate matter emissions testing was conducted on all but three engines: F100-GE-129, F100-PW-100, and F100-PW-229. The test methodology used to measure particulate matter varied depending on the design of each test cell and each exhaust configuration. The particulate matter emissions measurements that were collected using the strict EPA Method 5 guidelines are listed in Table 4. The emissions reported in Table 4 are the average of three runs. Results of individual runs are presented in Volume 2 of this report. The remaining particulate matter emission results are tentative and are not included in the Executive Summary.

4.3 HAZARDOUS AIR POLLUTANTS

Tables 5 through 21 depict the average HAP emissions for each power setting of each engine tested. These tables combine and summarize semivolatile, volatile, and aldehyde/ketones compounds. The 11 HAPs shown in Tables 5 through 21 are the most frequently detected HAPs that are combustion by-products. Within these tables, HAPs have been totaled for each power setting. The Total HAPs value shown on each table indicates the sum for the eleven HAPs that are considered products of combustion. The remaining HAP data that was analyzed for during this sampling program is presented in Volume 2 of this report.

Also presented in Figures 2 through 18 are graphical representations of the HAP results. The contribution of benzene and formaldehyde to the total HAP quantity is discussed in the recommendation section. Table 22 provides a summary of engine operating data that was collected during each emission test throughout this program.

5.0 RECOMMENDATIONS

The following recommendations pertain to future engine testing and data analysis. Additional recommendations are contained in Volume 2 of this report.

During the testing program over 120 individual compounds were sampled and analyzed, but only a small percentage of those compounds was detected repeatedly. Those compounds that were detected had concentrations significantly above the analytical detection levels. Depending on the use of this data, it may be justifiable to reduce the compounds sampled in subsequent programs to only those compounds that were detected during this program. This is based on the assumption that sufficient HAP data was gathered during this program that can be directly applied to future engines. Any future sampling must take into account what the potential use of the data may be (health risk, HAP qualification/quantification, regulatory, etc.) and then determine what compounds need to be sampled.

Likewise if similar test methodologies, as applied during this program, are used to collect and analyze for various compounds, no significant cost savings would be achieved in reducing the number of compounds analyzed for in a specific test method (i.e., sampling for VOCs by EPA method 0030 and only analyzing for benzene, toluene, and xylene). If sampling is conducted by an alternate method requiring significantly less effort to collect the sample and analyze for fewer compounds, a significant cost savings may be achieved.

The data collected during this program can also be reviewed to determine if surrogate compounds can be used to predict other HAPs (i.e., can benzene be used to predict formaldehyde). Based on the data currently available, however, there are not sufficient data points at each engine conduction to do a meaningful analysis. If additional data was available, primarily at those engine conditions that have the highest emission rates, a statistically significant analysis could be conducted.

- Benzene, toluene, and xylene represent the most significant VOCs measured during the program. Future testing should concentrate on only these VOC HAPs.

- Formaldehyde surrogate for aldehydes group. Formaldehyde accounts for over 90% of total aldehydes/ketones. Future sampling should only be done for formaldehyde.

- Most HAP emissions occur during idle and afterburner modes. Future testing should concentrate on these modes to characterize emissions.

Table 4. Engine Emission Summary for Particulates

Engine/Condition	Filterable Particulate lbs/hr	Filterable Particulate lbs/1,000 lbs fuel	Total Particulate lbs/hr	Total Particulate lbs/1,000 lbs fuel
GTCP85-180				
Constant	0.15	0.55	0.19	0.72
GTCP165-1				
Constant	0.09	0.35	0.13	0.48
T700-GE-700				
Ground Idle	0.07	0.51	0.20	1.48
Flight Idle	0.56	1.19	0.59	1.26
Flight Max	0.81	1.29	1.39	2.22
Overspeed	1.01	1.39	1.89	2.60
T64-GE-100				
Ground Idle	0.06	0.22	0.70	2.36
75% Normal	1.43	1.52	1.85	1.97
Normal	1.24	0.73	2.73	1.61
Military	1.53	0.83	1.69	0.92

Table 5
Hazardous Air Pollutant Emissions Summary
T56-A-7 (C-130)

		Engine Operating Mode							
		Idle		Approach		Intermediate		Military	
Exhaust Flow Rate, dscfm		122,033		125,564		125,427		145,801	
Fuel Flow Rate, lbs/hr		724		880		1,742		2,262	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	2.97E-02	4.11E-02	2.94E-02	3.34E-02	1.62E-02	9.27E-03	8.62E-04	3.81E-04
Acetaldehyde	75070	7.54E-03	1.04E-02	0.00E+00	0.00E+00	9.46E-04	5.43E-04	3.72E-04	1.64E-04
Acrolein	107028								
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933	9.60E-05	1.33E-04	6.16E-05	7.00E-05			1.40E-04	6.18E-05
Naphthalene	91203	8.40E-04	1.16E-03	9.11E-04	1.04E-03	3.08E-04	1.77E-04	3.02E-04	1.34E-04
Benzene	71432	3.45E-03	4.76E-03	3.91E-03	4.45E-03	2.34E-03	1.34E-03	1.78E-03	7.86E-04
Toluene	108883	1.96E-03	2.71E-03	2.02E-03	2.29E-03	1.67E-03	9.60E-04	5.74E-05	2.52E-05
Ethylbenzene	100414			5.45E-04	6.19E-04	5.46E-04	3.12E-04	4.06E-04	1.80E-04
m,p-Xylene	1330207	2.24E-04	3.11E-04	6.44E-04	7.32E-04	7.22E-04	4.15E-04	1.42E-03	6.28E-04
o-Xylene	95476			2.84E-04	3.23E-04	2.92E-04	1.68E-04	5.62E-04	2.49E-04
Styrene	100425			3.22E-04	3.66E-04				
Total HAPs		4.39E-02	6.06E-02	3.81E-02	4.33E-02	2.30E-02	1.32E-02	5.90E-03	2.61E-03

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 2
Hazardous Air Pollutant Emissions Summary - T56-A-7 (C-130)

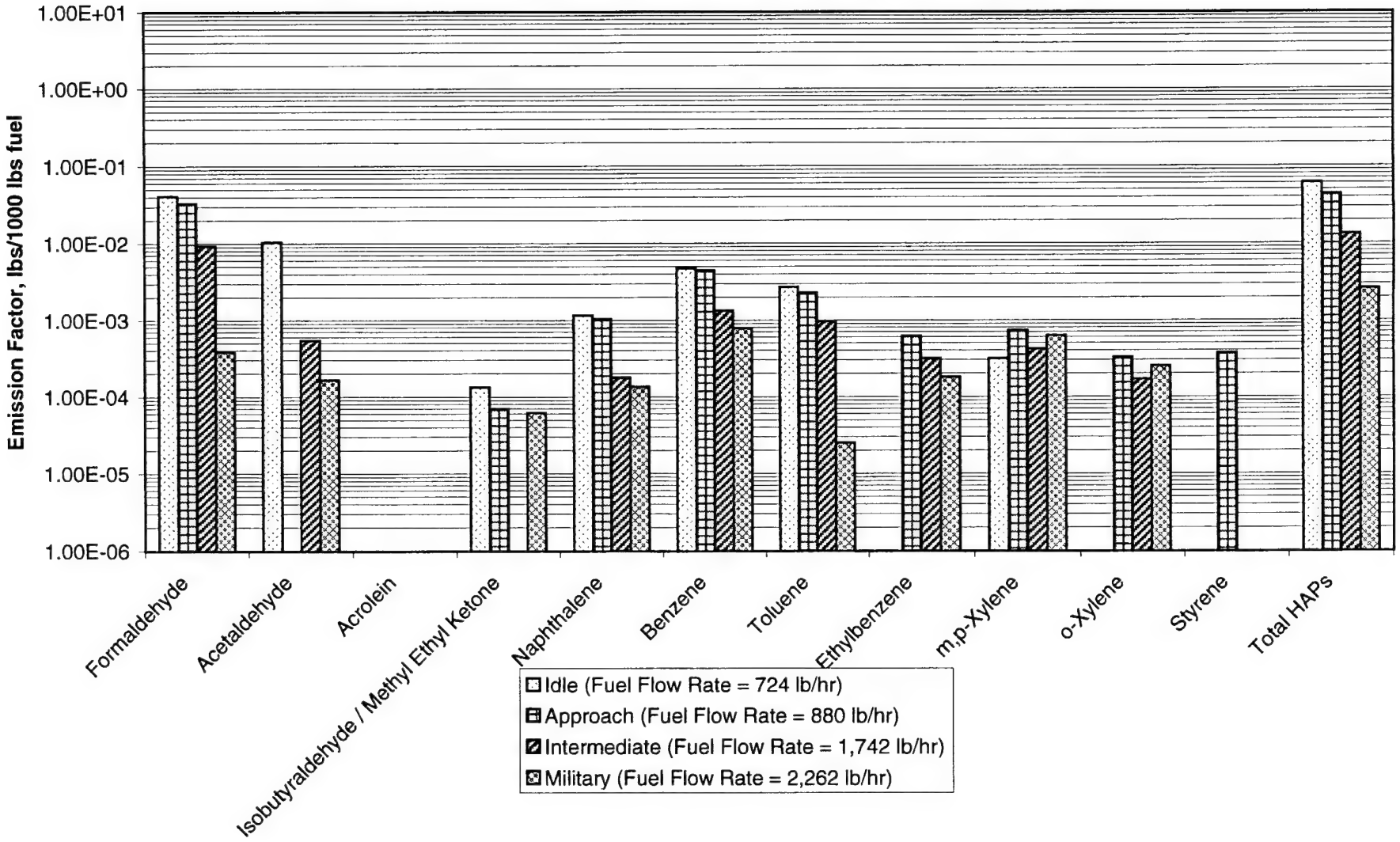


Table 6
Hazardous Air Pollutant Emissions Summary
TF39-GE-1C(C-5)

		Engine Operating Mode							
		Idle		Approach		Intermediate		Military	
Exhaust Flow Rate, dscfm		510,030		1,844,298		2,028,301		2,147,268	
Fuel Flow Rate, lbs/hr		1,448		10,477		12,541		13,862	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	2.06E+00	1.42E+00	8.54E-02	8.15E-03	6.14E-02	4.90E-03	1.46E-01	1.06E-02
Acetaldehyde	75070	3.07E-01	2.12E-01	3.31E-02	3.16E-03	3.27E-03	2.61E-04	8.55E-03	6.17E-04
Acrolein	107028	2.99E-01	2.06E-01						
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933	5.35E-02	3.69E-02			2.95E-03	2.35E-04	3.41E-03	2.46E-04
Naphthalene	91203	1.41E-01	9.71E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Benzene	71432	5.18E-01	3.57E-01	1.63E-02	1.56E-03	1.76E-02	1.41E-03	2.99E-02	2.16E-03
Toluene	108883	1.86E-01	1.28E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Ethylbenzene	100414	2.91E-02	2.00E-02	1.86E-02	1.78E-03	6.26E-03	4.99E-04	0.00E+00	0.00E+00
m,p-Xylene	1330207	5.52E-02	3.80E-02	0.00E+00	0.00E+00	2.38E-02	1.90E-03	0.00E+00	0.00E+00
o-Xylene	95476	2.90E-02	2.00E-02	1.62E-02	1.57E-03	8.57E-03	6.83E-04	0.00E+00	0.00E+00
Styrene	100425	6.51E-02	4.48E-02					1.28E-02	9.26E-04
Total HAPs		3.74E+00	2.58E+00	1.70E-01	1.62E-02	1.24E-01	9.89E-03	2.01E-01	1.45E-02

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 3
Hazardous Air Pollutant Emissions Summary - TF39-GE-1C (C-5)

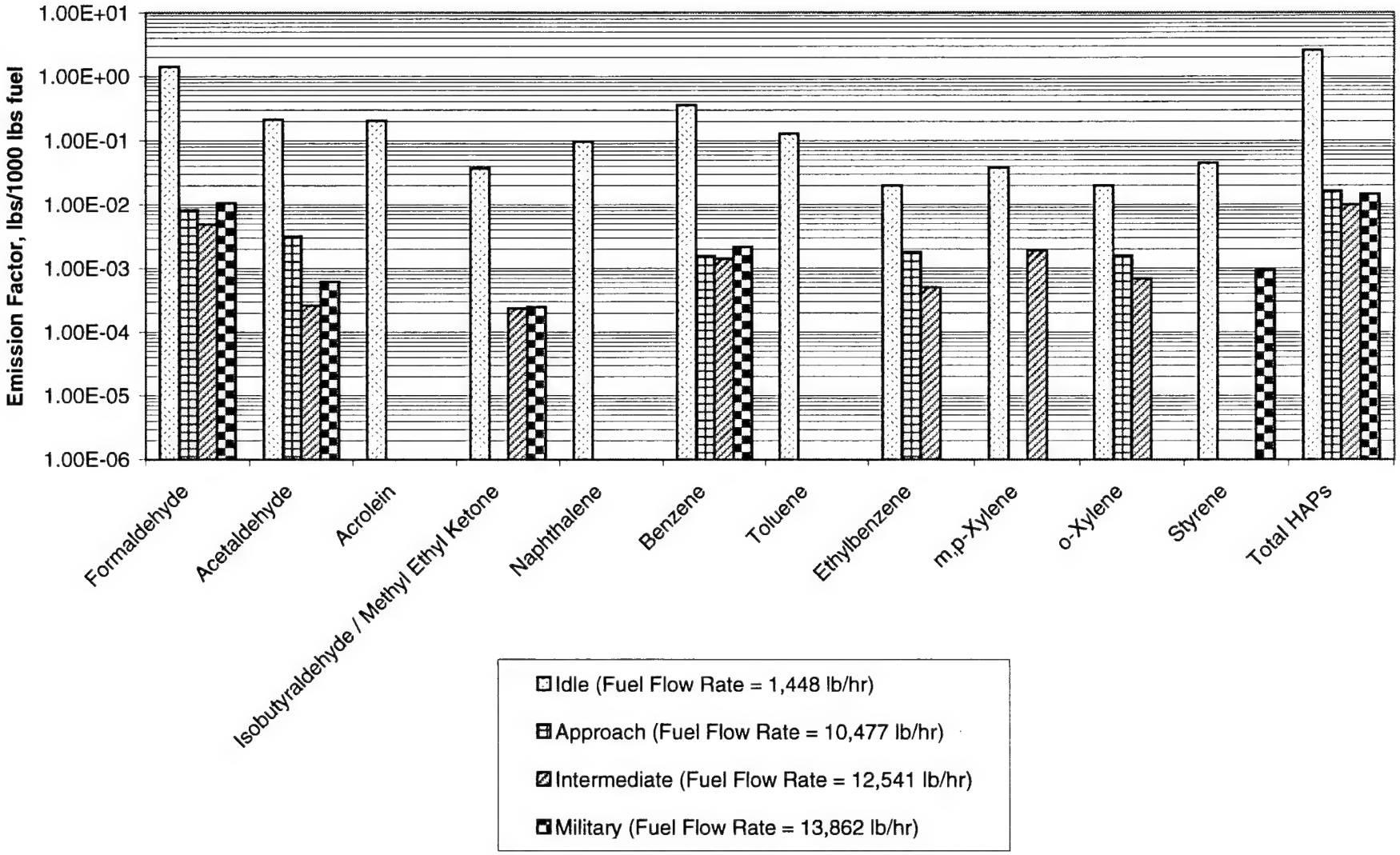


Table 7
Hazardous Air Pollutant Emissions Summary
GTCP85-180 (APU)

		Engine Operating Mode	
		Constant	
Exhaust Flow Rate, dscfm		5,542	
Fuel Flow Rate, lbs/hr		270	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	5.50E-03	2.03E-02
Acetaldehyde	75070	5.64E-04	2.09E-03
Acrolein	107028	8.22E-05	3.04E-04
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933		
Naphthalene	91203	0.00E+00	0.00E+00
Benzene	71432	4.05E-03	1.50E-02
Toluene	108883	1.18E-03	4.36E-03
Ethylbenzene	100414	3.26E-05	1.21E-04
m,p-Xylene	1330207	6.37E-04	2.36E-03
o-Xylene	95476	8.85E-05	3.28E-04
Styrene	100425	5.16E-05	1.91E-04
Total HAPs		1.22E-02	4.51E-02

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 4
Hazardous Air Pollutant Emissions Summary - GTCP85-180 (APU)

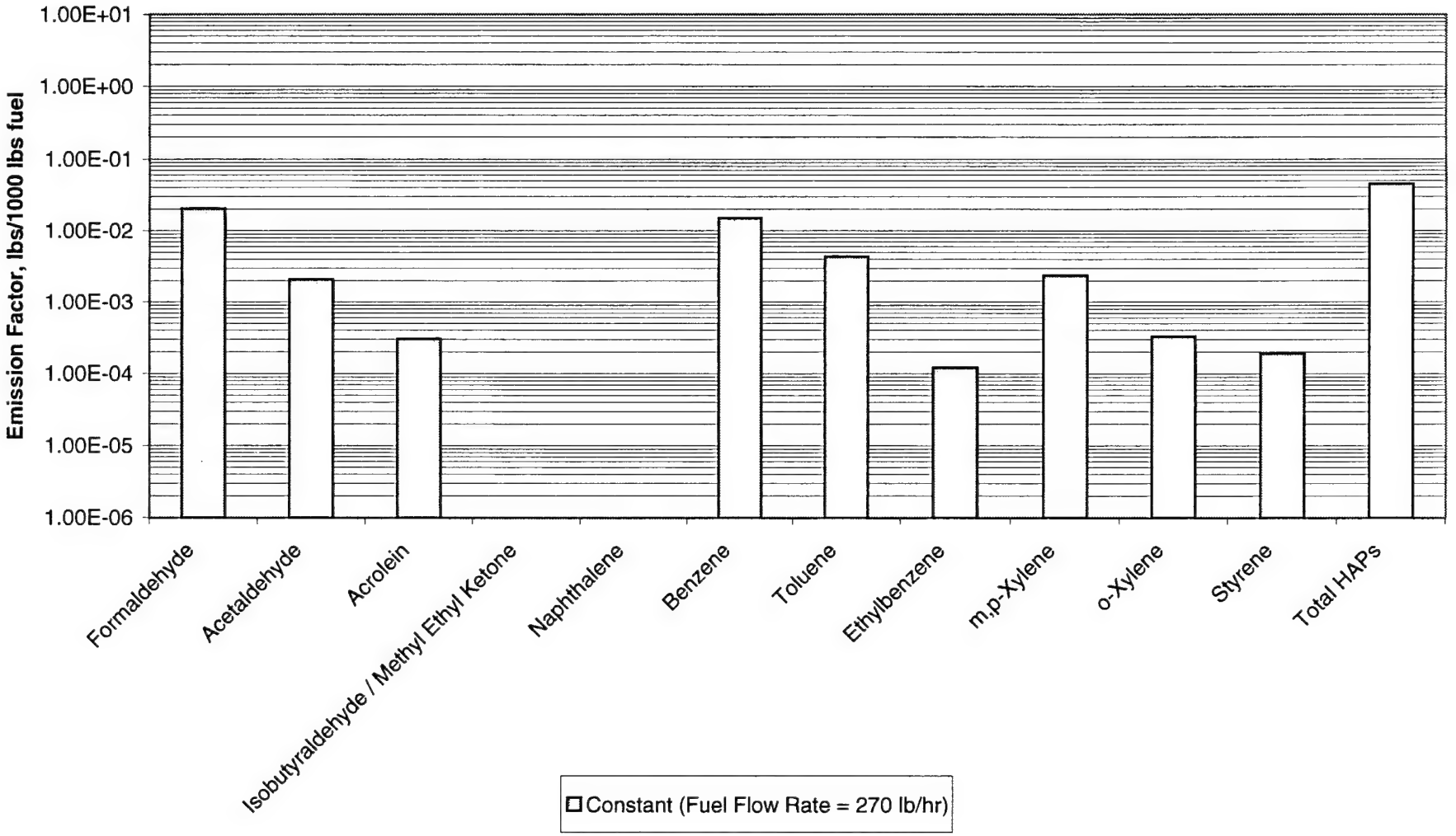


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Table 8
Hazardous Air Pollutant Emissions Summary
GTCP165-1 (APU)

		Engine Operating Mode	
		Constant	
Exhaust Flow Rate, dscfm		5,306	
Fuel Flow Rate, lbs/hr		273	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	5.12E-03	1.88E-02
Acetaldehyde	75070	1.53E-03	5.62E-03
Acrolein	107028		
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933	4.82E-04	1.77E-03
Naphthalene	91203	1.51E-03	5.55E-03
Benzene	71432	1.03E-02	3.86E-02
Toluene	108883	5.10E-03	1.89E-02
Ethylbenzene	100414	2.35E-04	8.78E-04
m,p-Xylene	1330207	1.32E-03	4.91E-03
o-Xylene	95476	3.19E-04	1.19E-03
Styrene	100425	6.11E-04	2.26E-03
Total HAPs		2.65E-02	9.85E-02

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Figure 5
Hazardous Air Pollutant Emissions Summary - GTCP165-1 (APU)

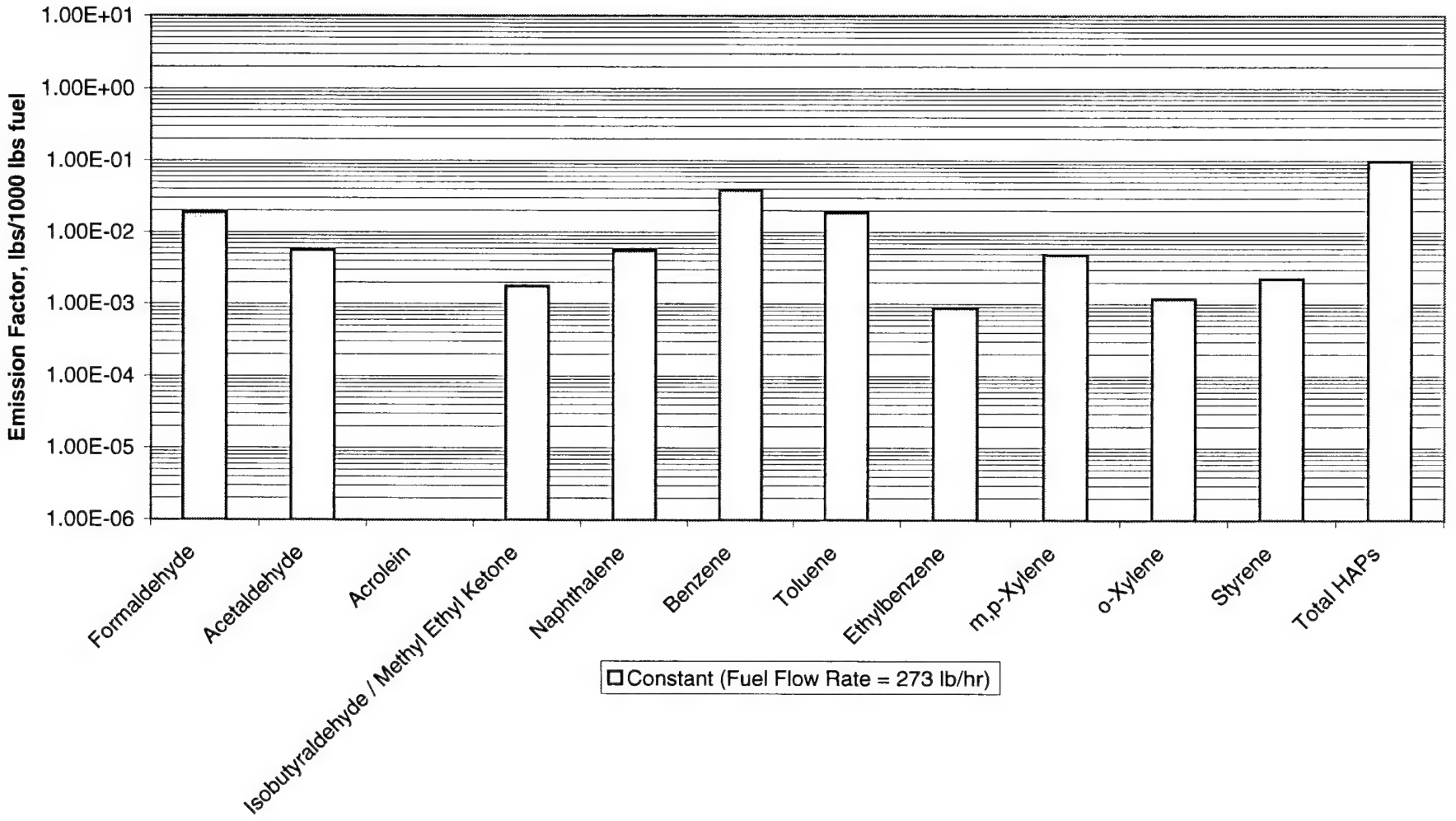

Table 9
Hazardous Air Pollutant Emissions Summary
J69-T-25 (T-37)

		Engine Operating Mode					
		Idle		Intermediate		Military	
Exhaust Flow Rate, dscfm		37,490		148,093		180,388	
Fuel Flow Rate, lbs/hr		167		872		1,085	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	1.53E-01	9.12E-01	2.37E-02	2.71E-02	1.26E-02	1.16E-02
Acetaldehyde	75070	1.63E-02	9.77E-02	1.86E-03	2.14E-03		
Acrolein	107028	3.27E-02	1.96E-01				
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933	6.18E-03	3.69E-02				
Naphthalene	91203	5.92E-03	3.54E-02	2.97E-04	3.41E-04	2.41E-04	2.22E-04
Benzene	71432	3.16E-02	1.89E-01	3.03E-03	3.47E-03	2.02E-03	1.86E-03
Toluene	108883	1.87E-02	1.12E-01	1.36E-03	1.56E-03	9.00E-04	8.29E-04
Ethylbenzene	100414	3.39E-03	2.03E-02				
m,p-Xylene	1330207	1.08E-02	6.43E-02	6.23E-04	7.14E-04	6.33E-04	5.83E-04
o-Xylene	95476	4.19E-03	2.51E-02	1.04E-03	1.19E-03		
Styrene	100425	4.54E-03	2.71E-02				
Total HAPs		2.87E-01	1.72E+00	3.19E-02	3.65E-02	1.64E-02	1.51E-02

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Figure 6
Hazardous Air Pollutant Emissions Summary - J69-T-25 (T-37)

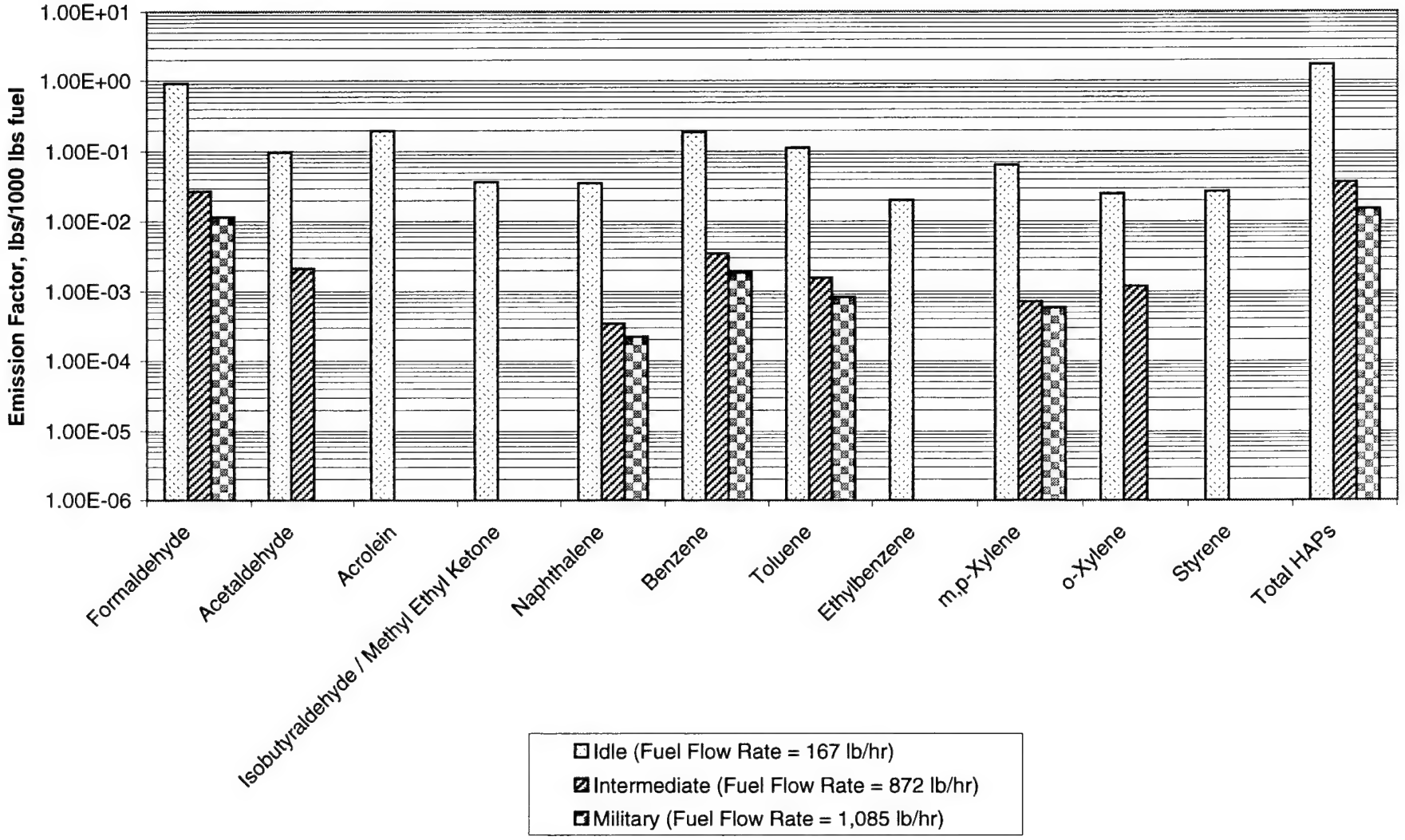

Table 10
Hazardous Air Pollutant Emissions Summary
J85-GE-5A (T-38)

		Engine Operating Mode							
		Idle		Intermediate		Military		Afterbubrner (Zone 1)	
Exhaust Flow Rate, dscfm		54,202		126,973		283,295		232,628	
Fuel Flow Rate, lbs/hr		434		950		2,740		8,138	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	9.81E-02	1.92E-01	5.18E-01	6.47E-01	2.02E-01	8.17E-02	1.95E-01	2.52E-02
Acetaldehyde	75070	5.12E-02	9.99E-02						
Acrolein	107028	1.17E-01	2.28E-01						
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933								
Naphthalene	91203	4.19E-02	8.19E-02	1.22E-02	1.52E-02	3.47E-03	1.40E-03	6.64E-03	8.60E-04
Benzene	71432	6.44E-02	1.26E-01	1.27E-01	1.59E-01	3.12E-02	1.26E-02	5.56E-02	7.20E-03
Toluene	108883	7.22E-02	1.41E-01	4.66E-02	5.82E-02	8.83E-03	3.56E-03	1.41E-02	1.83E-03
Ethylbenzene	100414	1.33E-02	2.59E-02	8.37E-03	1.05E-02	1.03E-03	4.14E-04	4.26E-03	5.52E-04
m,p-Xylene	1330207	4.29E-02	8.39E-02	2.42E-02	3.03E-02	3.55E-03	1.43E-03	1.53E-02	1.98E-03
o-Xylene	95476	1.67E-02	3.26E-02	1.02E-02	1.27E-02	1.34E-03	5.42E-04	7.35E-03	9.53E-04
Styrene	100425	1.81E-02	3.54E-02	1.22E-02	1.53E-02	1.38E-03	5.55E-04	2.32E-03	3.01E-04
Total HAPs		5.36E-01	1.05E+00	7.59E-01	9.48E-01	2.53E-01	1.02E-01	3.01E-01	3.89E-02

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Figure 7
Hazardous Air Pollutant Emissions Summary - J85-GE-5A

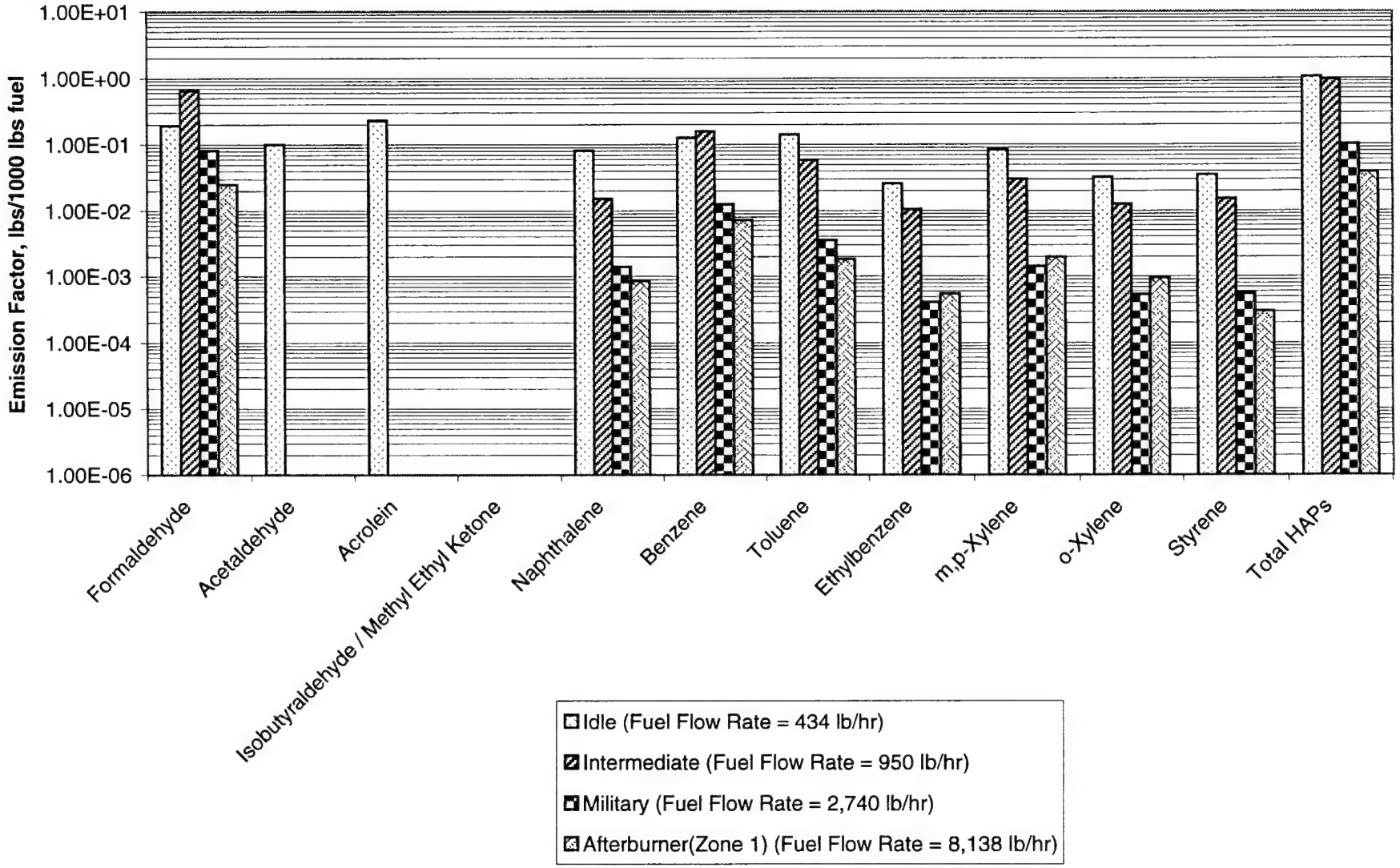

Table 11
Hazardous Air Pollutant Emissions Summary
T700-GE-700 (UH60A)

		Engine Operating Mode							
		Idle		Flight Idle		Flight Max		Overspeed	
Exhaust Flow Rate, dscfm		14,886		32,669		36,936		32,050	
Fuel Flow Rate, lbs/hr		134		469		626		725	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	2.94E-02	2.19E-01	1.92E-03	4.09E-03	NA	NA	3.49E-04	4.82E-04
Acetaldehyde	75070	2.42E-03	1.81E-02	1.42E-04	3.02E-04	NA	NA		
Acrolein	107028	9.69E-04	7.23E-03	4.54E-05	9.67E-05	NA	NA		
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933					NA	NA		
Naphthalene	91203	9.82E-04	7.33E-03	7.32E-05	1.56E-04	4.21E-05	6.73E-05	2.11E-05	2.91E-05
Benzene	71432	6.52E-03	4.87E-02	1.39E-04	2.97E-04	1.96E-04	3.13E-04	2.18E-04	3.00E-04
Toluene	108883	1.71E-03	1.28E-02	1.57E-04	3.35E-04	0.00E+00	0.00E+00	2.12E-04	2.92E-04
Ethylbenzene	100414	3.01E-04	2.25E-03	2.19E-04	4.66E-04			1.44E-04	1.98E-04
m,p-Xylene	1330207	5.83E-04	4.35E-03	1.49E-04	3.17E-04	2.02E-04	3.23E-04	6.06E-04	8.36E-04
o-Xylene	95476	3.75E-04	2.80E-03	1.69E-04	3.60E-04	1.15E-04	1.84E-04	2.94E-04	4.05E-04
Styrene	100425	6.92E-04	5.16E-03						
Total HAPs		4.40E-02	3.28E-01	3.01E-03	6.42E-03	5.55E-04	8.87E-04	1.84E-03	2.54E-03

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

NA - Sample Result Not Available

Figure 8
Hazardous Air Pollutant Emissions Summary-T700-GE-700

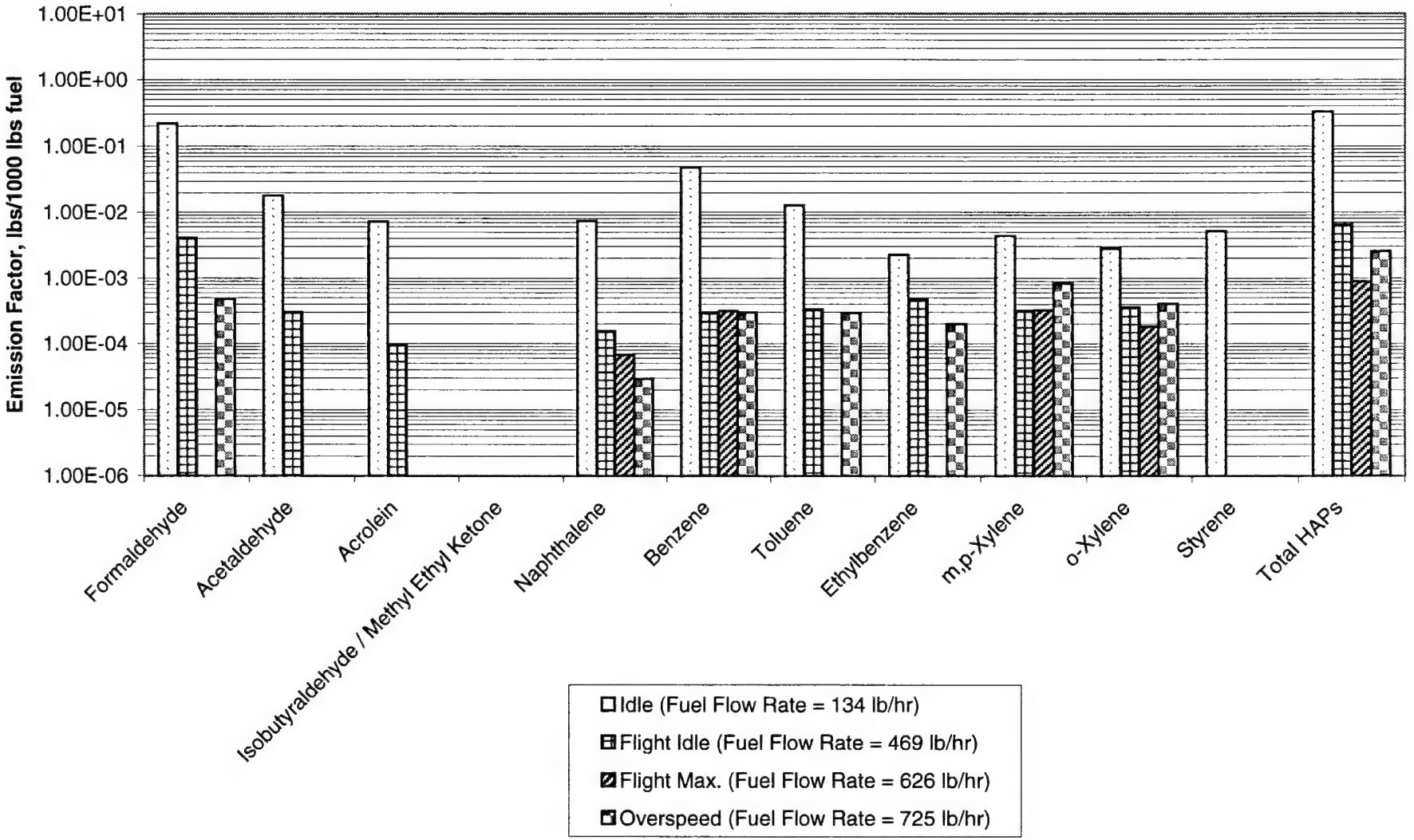

Table 12
Hazardous Air Pollutant Emissions Summary
TF33-P-102 (C/EC/RC-135E)

		Engine Operating Mode							
		Idle		Approach		Intermediate		Military	
Exhaust Flow Rate, dscfm		381,184		1,137,616		1,198,803		1,447,905	
Fuel Flow Rate, lbs/hr		1,114		4,737		5,782		7,561	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	1.05E+00	9.40E-01	3.15E-01	6.66E-02	1.31E-01	2.26E-02		
Acetaldehyde	75070	7.54E-03	1.04E-02	0.00E+00	0.00E+00				
Acrolein	107028								
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933								
Naphthalene	91203	2.39E-01	2.14E-01	5.22E-03	1.10E-03	4.25E-03	7.36E-04	9.82E-04	1.30E-04
Benzene	71432	7.90E-01	7.10E-01	5.40E-02	1.14E-02	2.34E-02	4.05E-03	7.22E-03	9.55E-04
Toluene	108883	2.95E-01	2.65E-01	1.08E-02	2.28E-03	1.53E-02	2.65E-03	7.19E-03	9.51E-04
Ethylbenzene	100414	9.63E-02	8.65E-02	3.90E-03	8.23E-04	3.56E-03	6.16E-04		
m,p-Xylene	1330207	1.53E-01	1.37E-01	1.14E-02	2.41E-03	6.40E-03	1.11E-03	6.31E-03	8.34E-04
o-Xylene	95476	6.79E-02	6.10E-02	0.00E+00	0.00E+00	1.59E-03	2.74E-04	2.85E-03	3.77E-04
Styrene	100425	1.21E-01	1.09E-01	5.61E-03	1.18E-03	3.32E-03	5.75E-04		
Total HAPs		2.82E+00	2.53E+00	4.06E-01	8.58E-02	1.89E-01	3.26E-02	2.46E-02	3.25E-03

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 9
Hazardous Air Pollutant Emissions Summary - TF33-P-102 (C/EC/RC-135E)

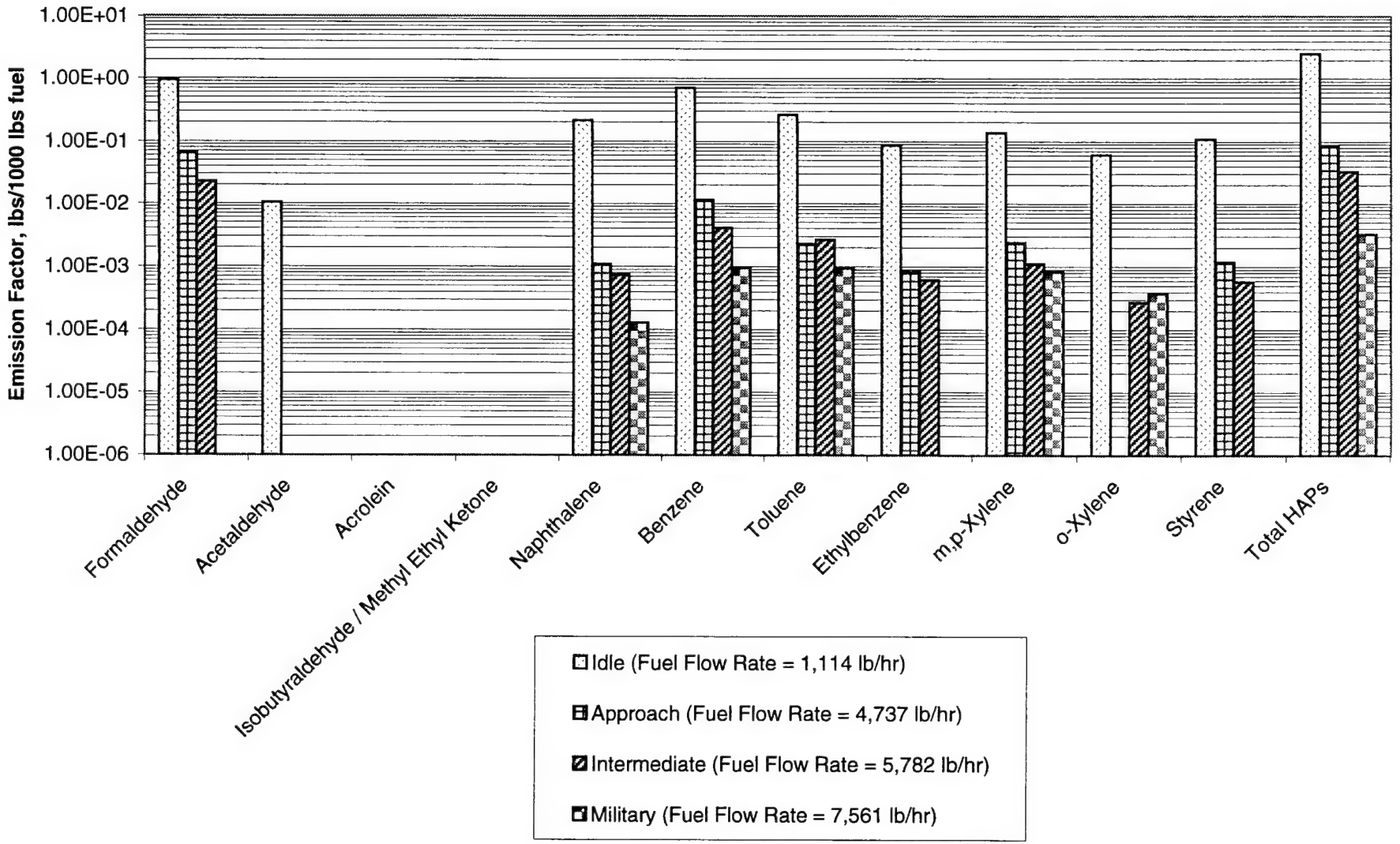

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Table 13
Hazardous Air Pollutant Emissions Summary
TF33-P-7/7A (C-141)

		Engine Operating Mode							
		Idle		Approach		Intermediate		Military	
Exhaust Flow Rate, dscfm		405,704		1,204,556		1,399,791		1,413,363	
Fuel Flow Rate, lbs/hr		1,093		4,884		6,356		8,264	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	2.52E+00	2.31E+00	6.41E-01	1.26E-01	1.78E-01	2.80E-02	4.36E-02	5.28E-03
Acetaldehyde	75070			4.26E-02	8.73E-03				
Acrolein	107028								
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933								
Naphthalene	91203	4.06E-01	3.71E-01	1.53E-02	3.14E-03	2.25E-03	3.55E-04	0.00E+00	0.00E+00
Benzene	71432	5.72E-01	5.20E-01	1.38E-01	2.85E-02	4.13E-02	6.49E-03	1.21E-02	1.47E-03
Toluene	108883	4.08E-01	3.73E-01	4.94E-02	1.02E-02	1.61E-02	2.54E-03	1.87E-02	2.27E-03
Ethylbenzene	100414	2.19E-01	2.00E-01	9.97E-03	2.06E-03	3.25E-03	5.11E-04	3.64E-03	4.42E-04
m,p-Xylene	1330207	3.66E-01	3.35E-01	1.66E-02	3.42E-03	6.61E-03	1.04E-03	1.00E-02	1.21E-03
o-Xylene	95476	1.39E-01	1.27E-01	6.93E-03	1.43E-03	2.81E-03	4.42E-04	3.99E-03	4.84E-04
Styrene	100425	2.65E-01	2.42E-01	1.68E-02	3.45E-03	4.74E-03	7.46E-04		
Total HAPs		4.90E+00	4.48E+00	9.37E-01	1.87E-01	2.55E-01	4.01E-02	9.20E-02	1.12E-02

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 10
Hazardous Air Pollutant Emissions Summary - TF33-P-7/7A (C-141)

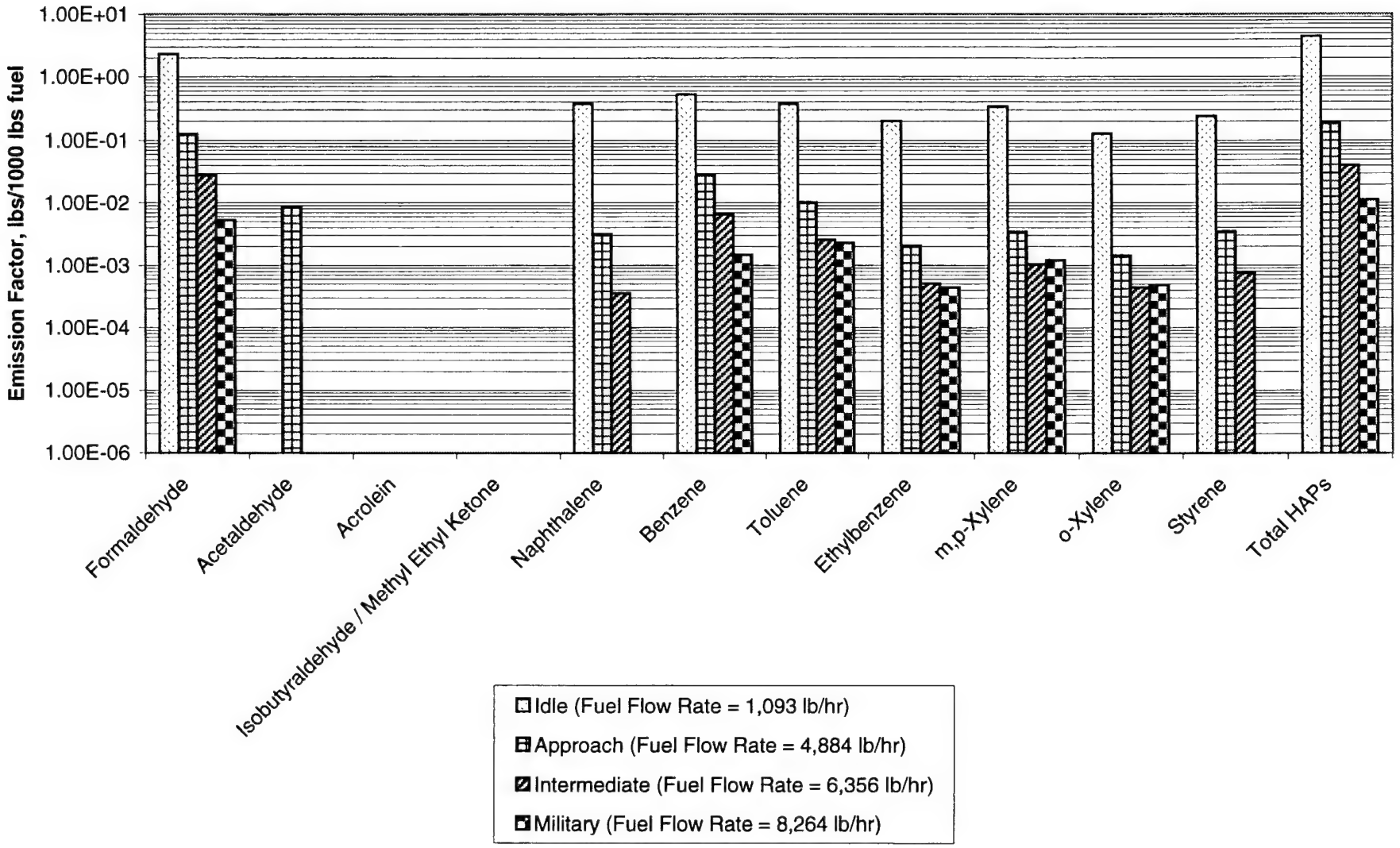

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Table 14
Hazardous Air Pollutant Emissions Summary
F108-CF-100 (KC-135R)

		Engine Operating Mode							
		Idle		Approach		Intermediate		Military	
Exhaust Flow Rate, dscfm		560,356		1,001,891		1,502,652		1,588,899	
Fuel Flow Rate, lbs/hr		1,136		2,547		5,650		6,458	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	1.08E-01	9.53E-02	3.83E-02	1.50E-02	3.15E-02	5.58E-03	4.53E-02	7.01E-03
Acetaldehyde	75070	0.00E+00	0.00E+00						
Acrolein	107028								
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933	6.21E-03	5.47E-03						
Naphthalene	91203	3.30E-03	2.91E-03	0.00E+00	0.00E+00				
Benzene	71432	1.58E-02	1.39E-02	8.62E-03	3.38E-03	4.69E-03	8.30E-04	3.84E-03	5.94E-04
Toluene	108883	1.02E-02	8.97E-03	1.59E-02	6.23E-03	8.02E-03	1.42E-03	7.17E-03	1.11E-03
Ethylbenzene	100414	1.14E-03	1.00E-03	2.07E-03	8.11E-04				
m,p-Xylene	1330207	1.87E-03	1.65E-03	4.10E-03	1.61E-03	3.54E-03	6.27E-04	3.23E-03	5.00E-04
o-Xylene	95476			1.32E-03	5.17E-04				
Styrene	100425	1.69E-03	1.49E-03						
Total HAPs		1.48E-01	1.31E-01	7.03E-02	2.75E-02	4.78E-02	8.46E-03	5.95E-02	9.21E-03

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 11
Hazardous Air Pollutant Emissions Summary - F108-CF-100 (KC-135 R)

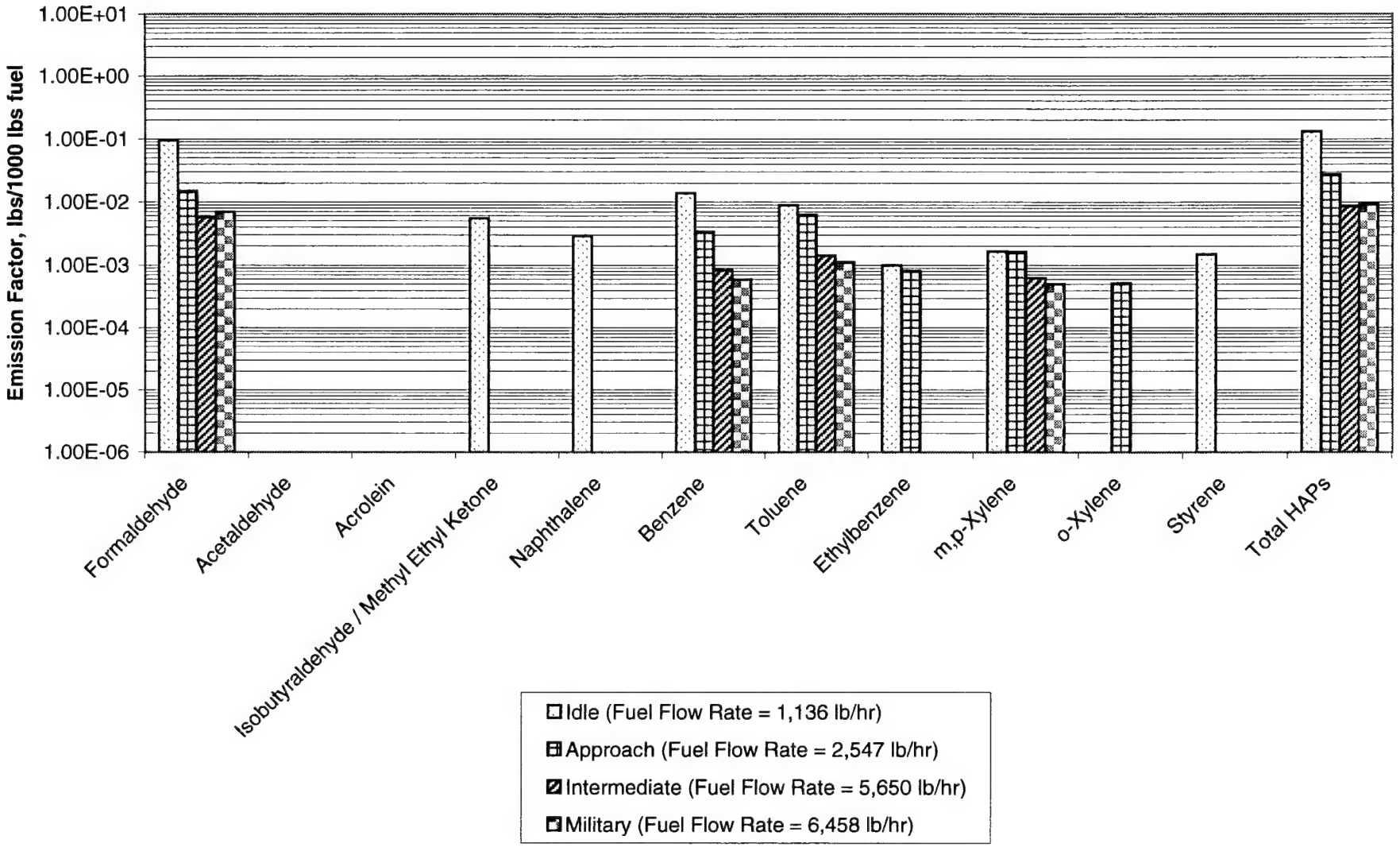

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Table 15
Hazardous Air Pollutant Emissions Summary
F101-GE-102 (B-1B)

		Engine Operating Mode									
		Idle		Approach		Intermediate		Military		Afterburner (Zone 1)	
Exhaust Flow Rate, dscfm		390,036		1,065,678		1,280,338		1,491,164		1,667,881	
Fuel Flow Rate, lbs/hr		1,117		4,533		6,557		7,828		15,314	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	1.16E-01	1.04E-01	2.32E-02	5.12E-03	3.04E-02	4.64E-03	3.47E-02	4.44E-03	5.96E-01	3.89E-02
Acetaldehyde	75070									2.71E-01	1.77E-02
Acrolein	107028									1.26E+00	8.24E-02
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933									2.27E-01	1.48E-02
Naphthalene	91203	2.00E-03	1.79E-03	0.00E+00	0.00E+00					1.94E+00	1.27E-01
Benzene	71432	1.32E-02	1.18E-02	3.58E-03	7.91E-04	8.67E-03	1.32E-03	4.29E-02	5.49E-03	3.49E+00	2.27E-01
Toluene	108883	6.20E-03	5.55E-03	6.79E-03	1.50E-03	1.11E-02	1.69E-03	1.45E-02	1.85E-03	1.94E+00	1.26E-01
Ethylbenzene	100414									1.32E+00	8.60E-02
m,p-Xylene	1330207	1.03E-03	9.22E-04	2.67E-03	5.90E-04	4.80E-03	7.31E-04	1.92E-02	2.46E-03	2.38E+00	1.55E-01
o-Xylene	95476									1.06E+00	6.91E-02
Styrene	100425	1.21E-03	1.08E-03			3.58E-03	5.45E-04			1.86E-01	1.21E-02
Total HAPs		1.40E-01	1.25E-01	3.62E-02	8.00E-03	5.86E-02	8.93E-03	1.11E-01	1.42E-02	1.47E+01	9.56E-01

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 12
Hazardous Air Pollutant Emissions Summary - F101-GE-102 (B-1B)

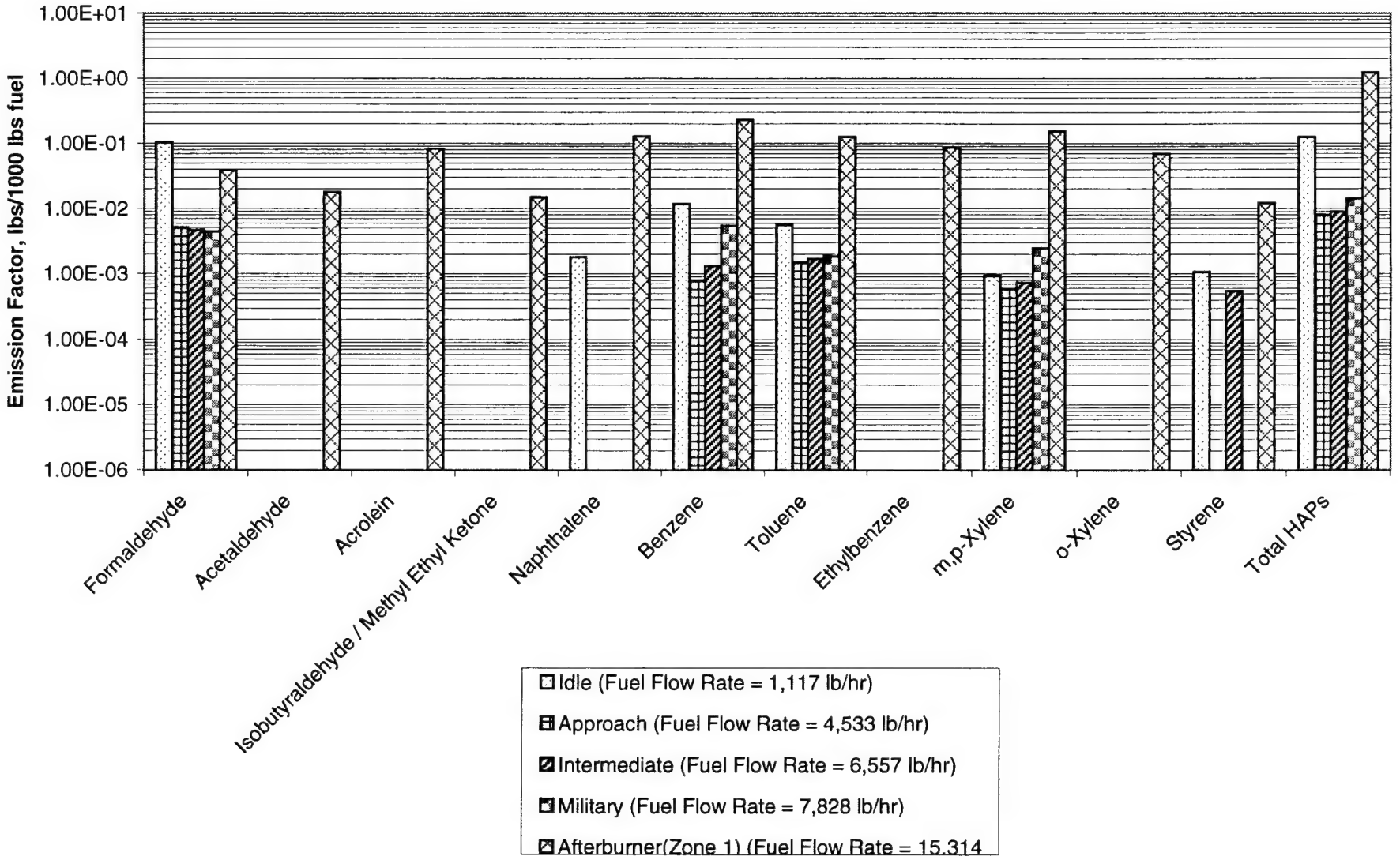

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Table 16
Hazardous Air Pollutant Emissions Summary
F110-GE-100 (F-16C/D)

		Engine Operating Mode									
		Idle		Approach		Intermediate		Military		Afterburner (Zone 1)	
Exhaust Flow Rate, dscfm		312,424		1,060,895		1,349,638		1,462,603		1,483,825	
Fuel Flow Rate, lbs/hr		1,111		5,080		7,332		11,358		18,088	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	1.12E-01	1.01E-01	5.09E-02	1.00E-02	1.42E-01	1.94E-02	1.74E-01	1.53E-02	2.76E-01	1.52E-02
Acetaldehyde	75070	7.36E-03	6.64E-03			1.21E-03	1.65E-04	1.64E-03	1.45E-04	2.24E-01	1.24E-02
Acrolein	107028									7.06E-01	3.90E-02
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933									1.00E-01	5.53E-03
Naphthalene	91203	2.68E-03	2.42E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00	3.76E-03	3.31E-04	1.76E+00	9.72E-02
Benzene	71432	3.26E-02	2.94E-02	9.00E-03	1.77E-03	1.16E-02	1.59E-03	1.83E-02	1.61E-03	3.39E+00	1.88E-01
Toluene	108883	1.22E-02	1.10E-02	6.82E-03	1.34E-03	1.39E-02	1.90E-03	8.43E-03	7.44E-04	2.54E+00	1.40E-01
Ethylbenzene	100414	2.22E-03	2.00E-03	2.34E-03	4.60E-04	3.60E-03	4.91E-04	2.84E-03	2.50E-04	8.10E-01	4.46E-02
m,p-Xylene	1330207	3.16E-03	2.85E-03	4.20E-03	8.27E-04	7.13E-03	9.71E-04	3.85E-03	3.39E-04	1.10E+00	6.03E-02
o-Xylene	95476	1.53E-03	1.38E-03	2.20E-03	4.33E-04	1.82E-03	2.45E-04	2.84E-03	2.50E-04	5.14E-01	2.83E-02
Styrene	100425	4.10E-03	3.70E-03	2.20E-03	4.33E-04	4.51E-03	6.14E-04	3.47E-03	3.06E-04	1.03E-01	5.69E-03
Total HAPs		1.78E-01	1.60E-01	7.77E-02	1.53E-02	1.86E-01	2.54E-02	2.19E-01	1.93E-02	1.15E+01	6.36E-01

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 13

Hazardous Air Pollutant Emissions Summary - F110-GE-100 (F-16C/D)

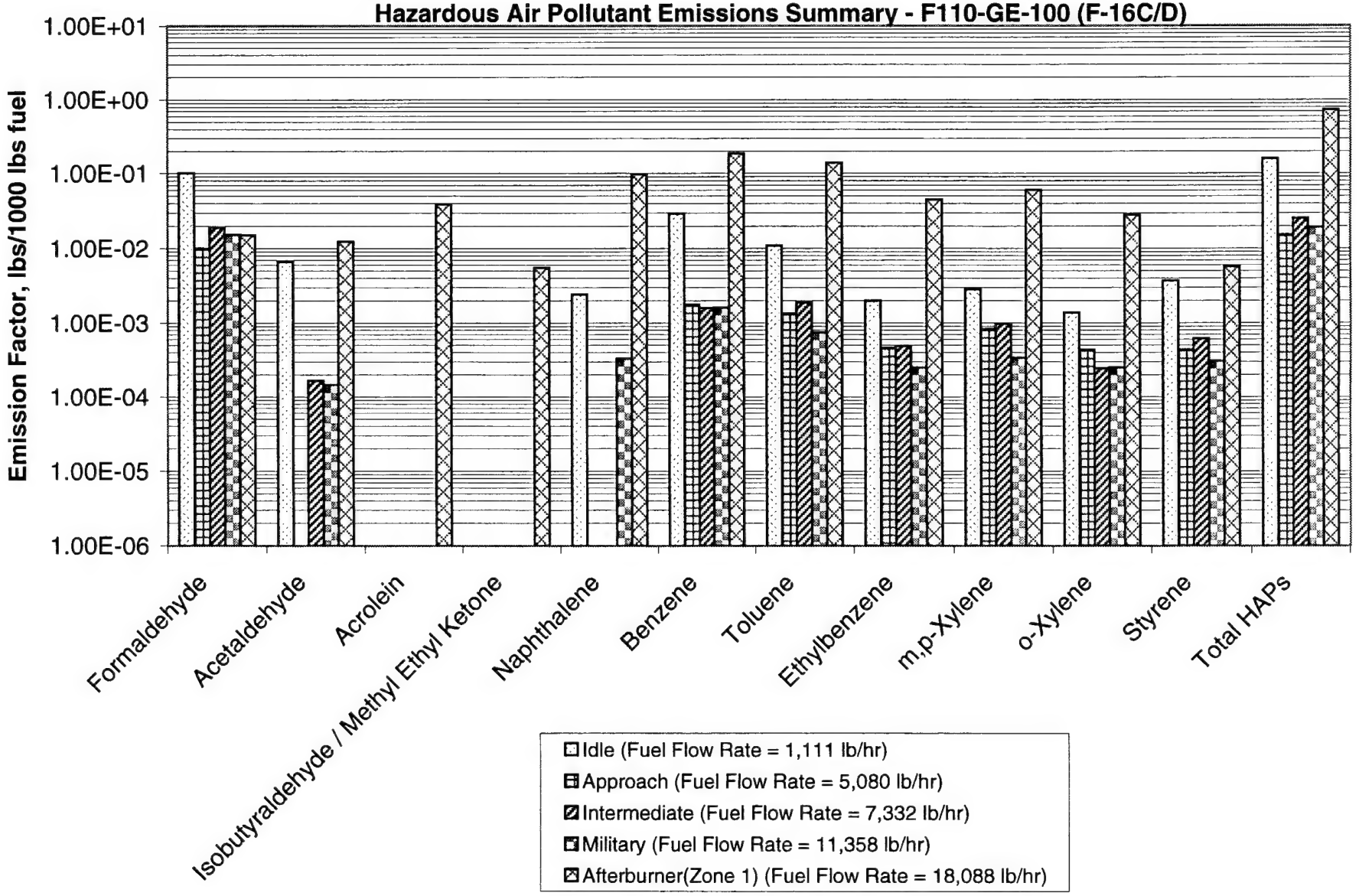

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Table 17
Hazardous Air Pollutant Emissions Summary
F117-PW-100 (C-17)

		Engine Operating Mode					
		Idle		Approach		Intermediate	
Exhaust Flow Rate, dscfm		358,477		1,250,171		1,885,330	
Fuel Flow Rate, lbs/hr		978		4,645		10,408	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	2.31E-01	2.33E-01	7.68E-02	1.65E-02	9.89E-02	9.51E-03
Acetaldehyde	75070	1.17E-02	1.18E-02				
Acrolein	107028						
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933						
Naphthalene	91203	2.34E-03	2.37E-03				
Benzene	71432	2.20E-02	2.20E-02	4.13E-03	8.89E-04	6.51E-03	6.26E-04
Toluene	108883	6.54E-03	6.60E-03	6.55E-03	1.41E-03	1.17E-02	1.12E-03
Ethylbenzene	100414	2.99E-03	3.02E-03				
m,p-Xylene	1330207	2.24E-03	2.26E-03	3.28E-03	7.04E-04	5.69E-03	5.47E-04
o-Xylene	95476	9.57E-04	9.66E-04				
Styrene	100425	1.52E-03	1.53E-03				
Total HAPs		2.81E-01	2.84E-01	9.08E-02	1.95E-02	1.23E-01	1.18E-02

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Figure 14
Hazardous Air Pollutant Emissions Summary - F117-PW-100 (C-17)

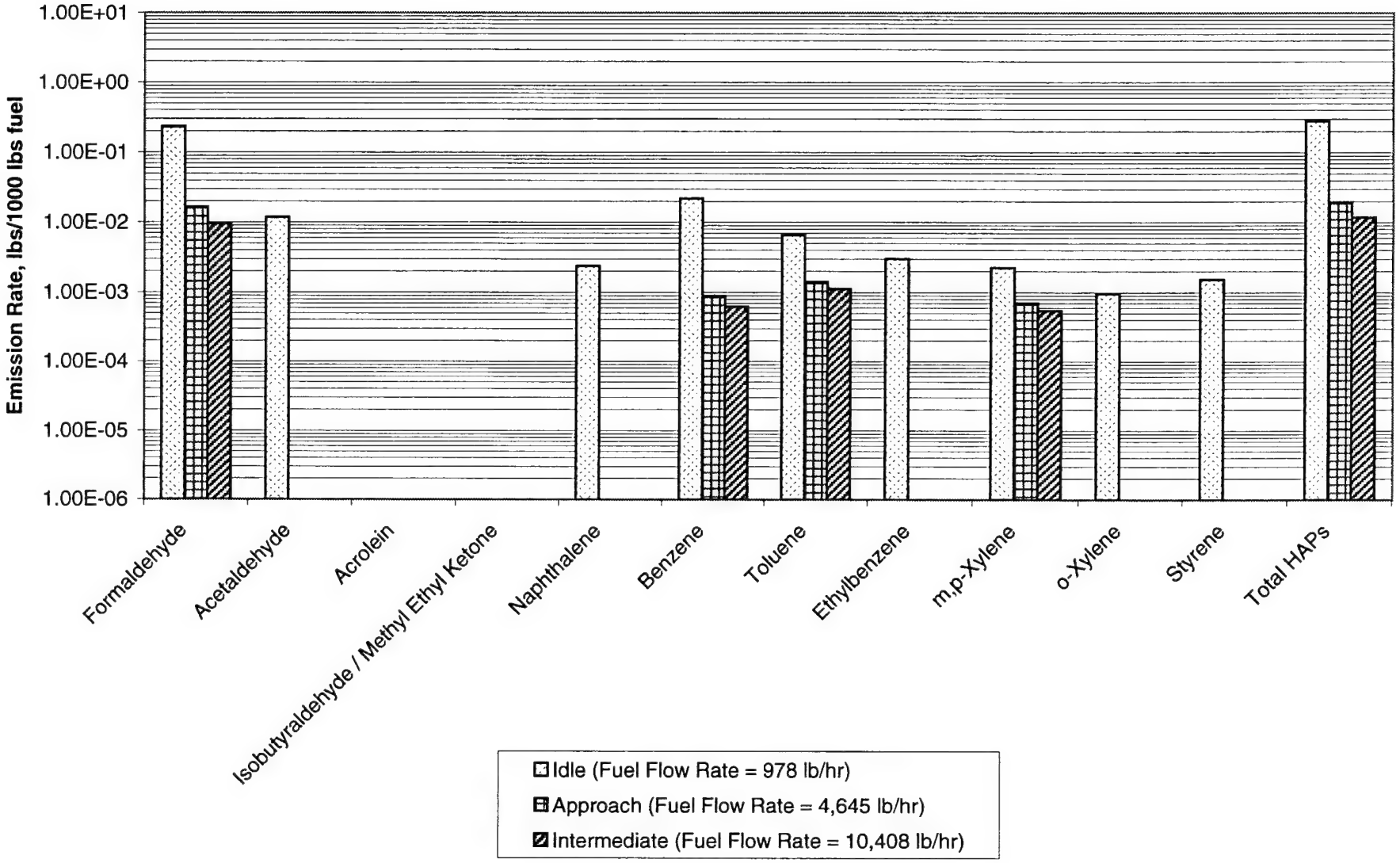

Table 18
Hazardous Air Pollutant Emissions Summary
F118-GE-100 (B-2)

		Engine Operating Mode							
		Idle		Approach		Intermediate		Military	
Exhaust Flow Rate, dscfm		304,256		718,198		858,447		1,057,742	
Fuel Flow Rate, lbs/hr		1,097		3,773		6,350		10,887	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	1.97E-01	1.80E-01	4.60E-02	1.22E-02	7.43E-02	1.17E-02	7.13E-02	6.55E-03
Acetaldehyde	75070	8.62E-03	7.85E-03						
Acrolein	107028								
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933								
Naphthalene	91203	0.00E+00	0.00E+00						
Benzene	71432	2.96E-02	2.70E-02	3.24E-03	8.57E-04	2.35E-03	3.71E-04	3.68E-03	3.38E-04
Toluene	108883	1.08E-02	9.87E-03	5.08E-03	1.34E-03	1.89E-03	2.97E-04	4.19E-03	3.84E-04
Ethylbenzene	100414	1.35E-03	1.23E-03	1.90E-03	5.03E-04				
m,p-Xylene	1330207	4.20E-03	3.83E-03	5.53E-03	1.46E-03	2.11E-03	3.32E-04	2.60E-03	2.38E-04
o-Xylene	95476	1.57E-03	1.43E-03	2.38E-03	6.28E-04				
Styrene	100425	2.47E-03	2.26E-03						
Total HAPs		2.56E-01	2.33E-01	6.41E-02	1.70E-02	8.07E-02	1.27E-02	8.18E-02	7.51E-03

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Results reported as 0.00 indicate a detected ambient pollutant concentration greater than the detected pollutant concentration in the exhaust stream.

Figure 15
Hazardous Air Pollutant Emission Summary - F118-GE-100 (B-2)

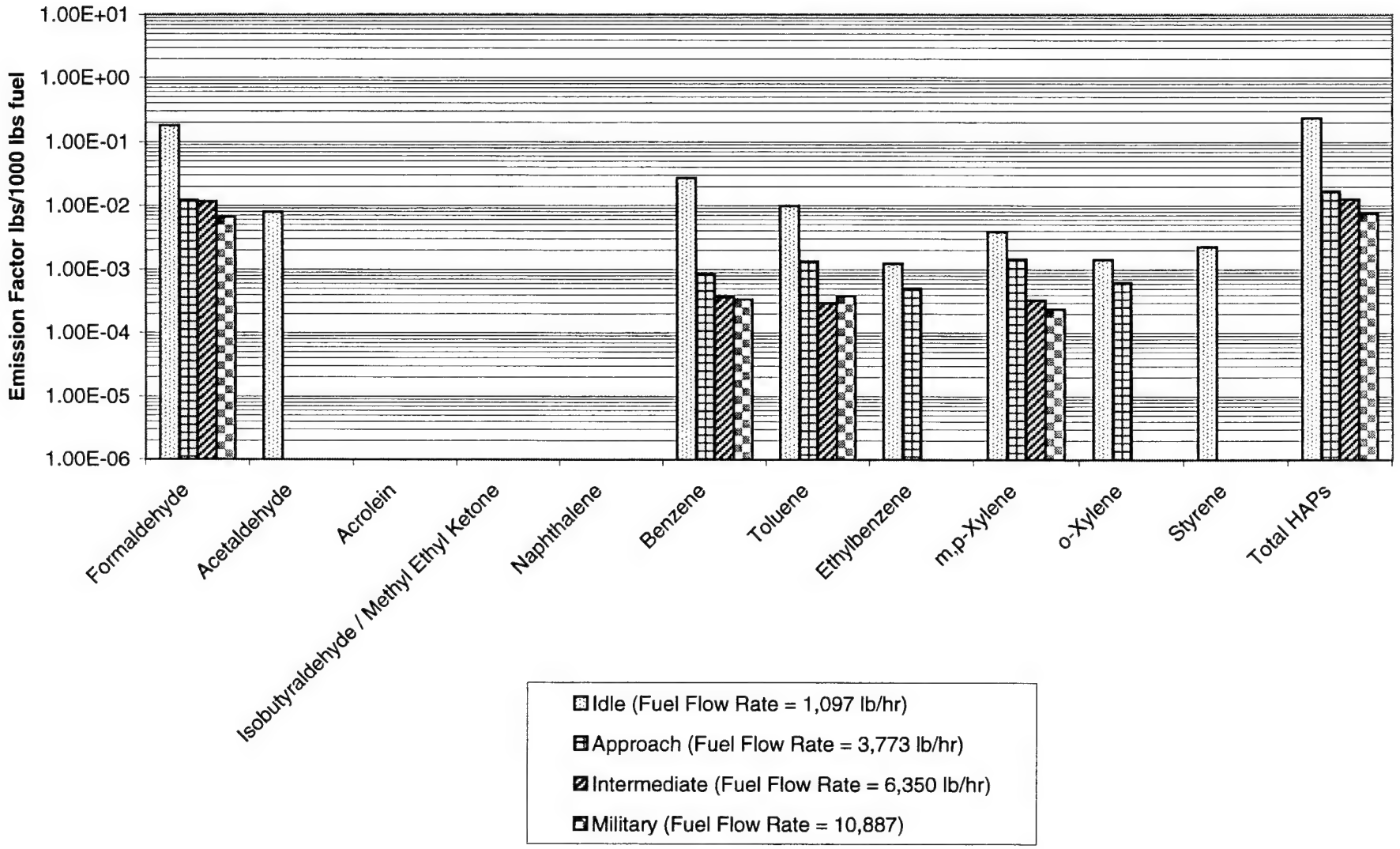

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Table 19
Hazardous Air Pollutant Emissions Summary
F404-GE-F1D2/400 (F-117A & F/A-18C/D)

		Engine Operating Mode									
		Idle		Approach		Intermediate		Military		Afterburner (Zone 3)	
Exhaust Flow Rate, dscfm		147,980		559,692		891,587		986,075		1,021,427	
Fuel Flow Rate, lbs/hr		685		3,111		6,464		7,739		15,851	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	7.82E-01	1.14E+00	5.20E-02	1.67E-02	1.46E-01	2.26E-02	6.98E-02	9.02E-03	5.93E-01	3.74E-02
Acetaldehyde	75070	3.90E-02	5.71E-02							5.36E-01	3.38E-02
Acrolein	107028	1.17E-01	1.71E-01							2.29E+00	1.45E-01
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933									3.44E-01	2.17E-02
Naphthalene	91203	8.95E-02	1.31E-01	9.65E-04	3.10E-04	4.55E-04	7.03E-05	7.99E-04	1.03E-04	1.16E+00	7.32E-02
Benzene	71432	3.52E-01	5.15E-01	2.35E-03	7.56E-04	4.17E-03	6.43E-04	5.70E-03	7.37E-04	5.86E+00	3.69E-01
Toluene	108883	1.78E-01	2.60E-01	2.72E-03	8.73E-04	6.91E-03	1.06E-03	5.13E-03	6.62E-04	2.83E+00	1.78E-01
Ethylbenzene	100414	5.13E-02	7.51E-02	1.51E-03	4.84E-04	2.58E-03	3.99E-04			7.70E-01	4.85E-02
m,p-Xylene	1330207	1.15E-01	1.68E-01	5.48E-03	1.76E-03	8.91E-03	1.37E-03	5.76E-03	7.45E-04	1.47E+00	9.30E-02
o-Xylene	95476	5.53E-02	8.10E-02	2.72E-03	8.75E-04	3.81E-03	5.88E-04	2.59E-03	3.35E-04	7.71E-01	4.86E-02
Styrene	100425	5.93E-02	8.69E-02							9.28E-02	5.85E-03
Total HAPs		1.84E+00	2.69E+00	6.77E-02	2.18E-02	1.73E-01	2.67E-02	8.98E-02	1.16E-02	1.67E+01	1.05E+00

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Figure 16
Hazardous Air Pollutant Emissions Summary - F404-GEF1D2/400 (F-117A & F/A-18C/D)

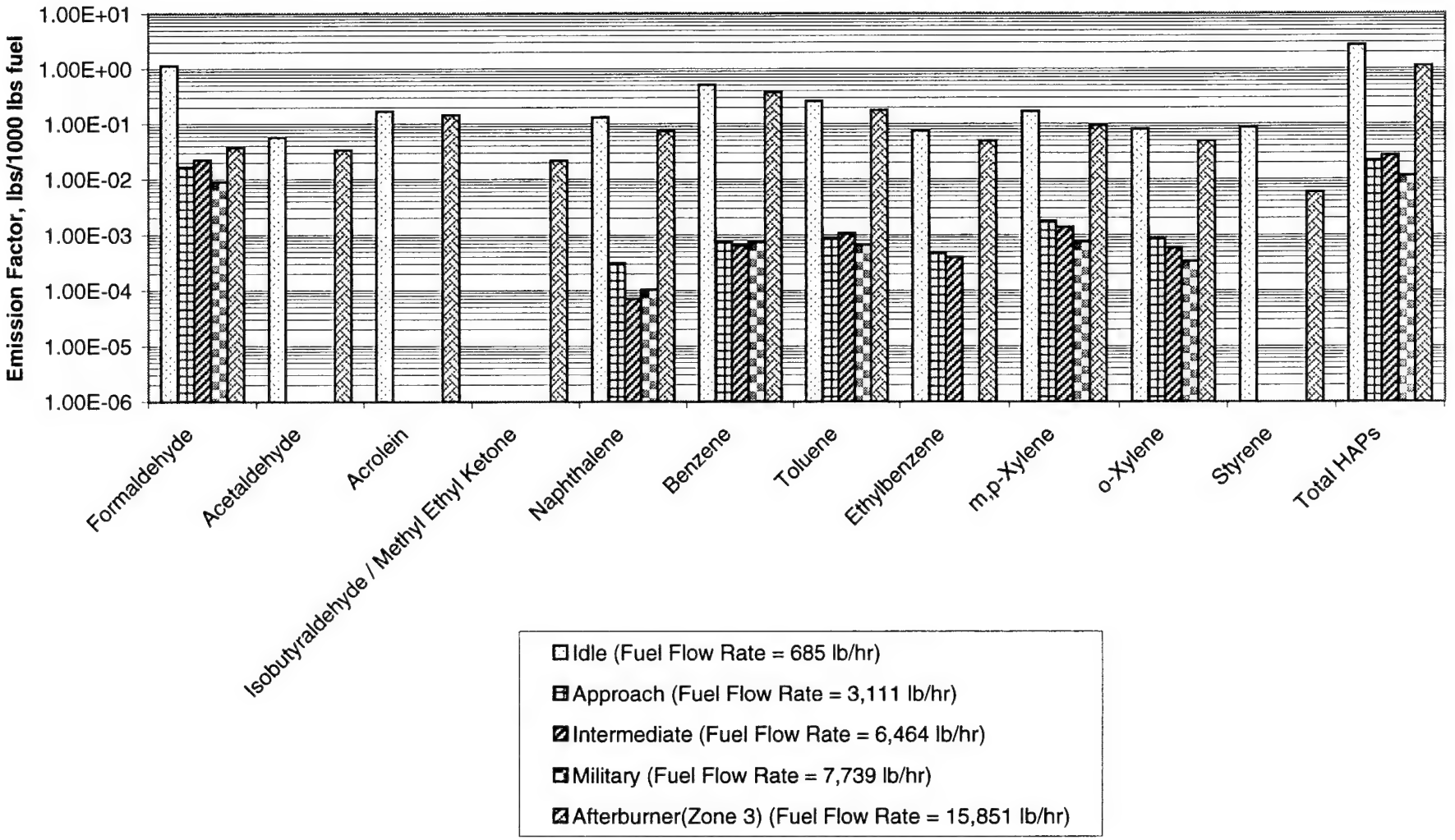

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Table 20
Hazardous Air Pollutant Emissions Summary
T64-GE-100 (MH53J)

		Engine Operating Mode							
		Ground Idle		75% Normal		Normal		Military	
Exhaust Flow Rate, dscfm		10,077		24,855		29,066		30,284	
Fuel Flow Rate, lbs/hr		298		941		1,698		1,848	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	2.13E-02	7.16E-02	1.10E-02	1.17E-02	5.40E-04	3.18E-04	3.39E-04	1.84E-04
Acetaldehyde	75070	1.51E-02	5.05E-02	1.13E-03	1.20E-03				
Acrolein	107028	3.39E-02	1.14E-01	1.29E-03	1.37E-03				
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933	5.78E-03	1.94E-02	3.60E-05	3.82E-05				
Naphthalene	91203	1.62E-02	5.44E-02	1.43E-03	1.52E-03	8.42E-06	4.96E-06	4.62E-03	2.50E-03
Benzene	71432	6.43E-02	2.16E-01	1.19E-02	1.27E-02	6.79E-03	3.98E-03	7.16E-03	3.88E-03
Toluene	108883	3.04E-02	1.02E-01	2.71E-03	2.88E-03	2.26E-04	1.33E-04	2.35E-04	1.27E-04
Ethylbenzene	100414	6.68E-03	2.25E-02	2.89E-04	3.07E-04				
m,p-Xylene	1330207	1.31E-02	4.39E-02	6.43E-04	6.83E-04				
o-Xylene	95476	6.16E-03	2.07E-02	2.68E-04	2.85E-04				
Styrene	100425	1.22E-02	4.11E-02	4.81E-04	5.11E-04				
Total HAPs		2.25E-01	7.56E-01	3.12E-02	3.32E-02	7.56E-03	4.44E-03	1.24E-02	6.69E-03

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Figure 17
Hazardous Air Pollutant Emissions Summary - T64-GE-100 (MH53J)

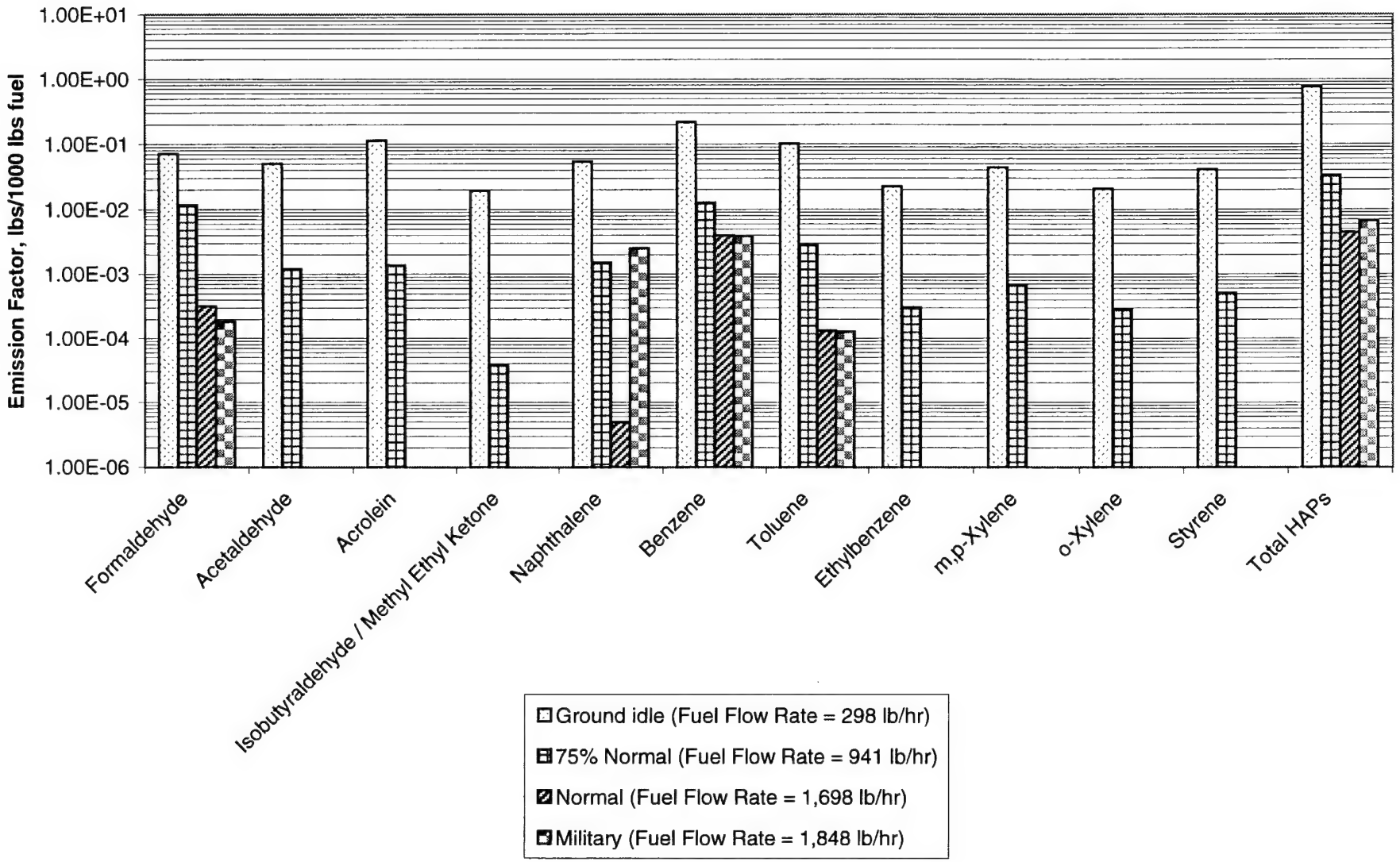

Table 21
Hazardous Air Pollutant Emissions Summary
TF34-GE-100A (A-10A/B)

		Engine Operating Mode							
		Idle		Approach		Intermediate		Military	
Exhaust Flow Rate, dscfm		225,007		671,179		888,311		1,165,805	
Fuel Flow Rate, lbs/hr		498		933		1,512		2,628	
Compound	**CAS Number**	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*	lbs/hr	lbs/1,000 lbs fuel*
Formaldehyde	50000	6.09E-01	1.22E+00	4.95E-01	5.31E-01	1.00E-01	6.62E-02	7.42E-02	2.82E-02
Acetaldehyde	75070	6.34E-02	1.27E-01	2.87E-02	3.07E-02				
Acrolein	107028	3.04E-02	6.11E-02	1.27E-02	1.36E-02	8.19E-03	5.41E-03	7.77E-03	2.96E-03
Isobutyraldehyde / Methyl Ethyl Ketone	78842/78933								
Naphthalene	91203	2.23E-02	4.47E-02	7.94E-03	8.51E-03	2.41E-03	1.59E-03	8.42E-05	3.20E-05
Benzene	71432	1.40E-01	2.86E-01	5.94E-02	6.37E-02	1.44E-02	9.55E-03	1.12E-02	4.25E-03
Toluene	108883	5.60E-02	1.15E-01	1.30E-02	1.40E-02	4.85E-03	3.21E-03	3.52E-04	1.33E-04
Ethylbenzene	100414	1.30E-02	2.68E-02	3.28E-03	3.51E-03			2.51E-03	9.56E-04
m,p-Xylene	1330207	2.74E-02	5.64E-02	7.42E-03	7.95E-03	2.30E-03	1.52E-03	6.33E-03	2.41E-03
o-Xylene	95476	1.33E-02	2.75E-02	3.40E-03	3.65E-03			2.66E-03	1.01E-03
Styrene	100425	2.20E-02	4.56E-02	6.27E-03	6.72E-03				
Total HAPs		9.97E-01	2.01E+00	6.37E-01	6.83E-01	1.32E-01	8.75E-02	1.05E-01	4.00E-02

This table summarizes the hazardous air pollutants which are typical fuel combustion by-products. An expanded pollutant target list and data qualifiers are provided in Volume II.

Note: A blank represents a compound that was not detected.

* - Emission factors provided in pounds per thousand pounds of fuel were calculated using the lbs/hr rate and the fuel flow rate.

Figure 18
Hazardous Air Pollutant Emissions Summary - TF34-GE-100A (A-10A/B)

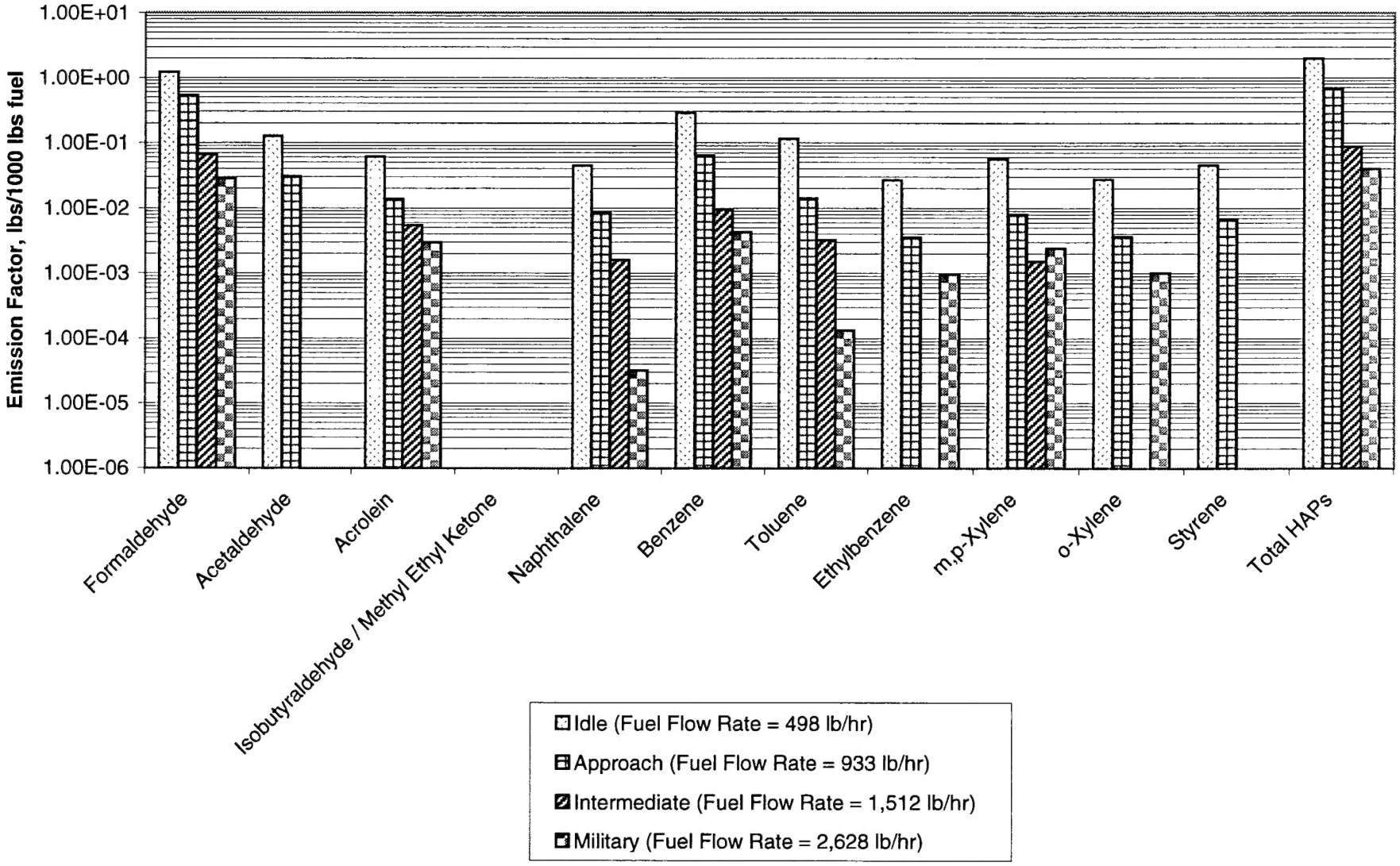

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Table 22. Engine Operation Summary

Engine Type	Operation Mode	Fuel flow, lbs/hr	Torque, Inch-Pounds	Shaft Horsepower	% Maximum Horsepower	Average Thrust, lbs	% Maximum Thrust
T56-A-7	Idle	723.6	1,011	217	4.7	---	---
	Approach	880.2	3,231	688	15.0	---	---
	Intermediate	1,741.9	12,802	2,808	61.2	---	---
	Military	2,261.7	18,754	4,115	89.6	---	---
TF39-GE-1C	Idle	1,448.3	---	---	---	2,955	7
	Approach	10,477.4	---	---	---	31,880	76
	Intermediate	12,541.3	---	---	---	36,617	87
	Military	13,861.8	---	---	---	39,486	94
GTCP85-180	Constant	270.3	100	67	(a)	---	---
GTCP165-1	Constant	272.6	217	132	(a)	---	---
T700-GE-700	Ground Idle	134	384	62	3.8	---	---
	Flight Idle	469	2,700	906	55.9	---	---
	Flight Max	626	4,008	1,333	82.2	---	---
	Overspeed	725	4,848	1,620	99.8	---	---
J69-T25A	Idle	167	---	---	---	73.22	4.3
	Intermediate	872	---	---	---	643	62.7
	Military	1,085	---	---	---	864	84.3
J85-GE-5A	Idle	434	---	---	---	97	3.6
	Intermediate	950	---	---	---	400	15.0
	Military	2,740	---	---	---	2,349	88.0
	Afterburner	8,138	---	---	---	3,310	116.0
F108-CF-100	Idle	1,136	---	---	---	1,990	9.2
	Approach	2,547	---	---	---	6,591	30.5
	Intermediate	5,650	---	---	---	15,123	69.9
	Military	6,458	---	---	---	16,978	78.5
TF33-P-7/7A	Idle	1,093	---	---	---	814	3.9
	Approach	4,884	---	---	---	9,349	44.5
	Intermediate	6,356	---	---	---	12,236	58.3
	Military	8,264	---	---	---	15,349	73.1
F101-GE-102	Idle	1,117	---	---	---	892	5.0
	Approach	4,533	---	---	---	8,143	47.0
	Intermediate	6,557	---	---	---	11,507	66.0
	Military	7,828	---	---	---	13,477	77.0
	Afterburner	15,314	---	---	---	18,460	106.0
TF33-P-102	Idle	1,114	---	---	---	976	5.4
	Approach	4,737	---	---	---	8,783	48.9
	Intermediate	5,782	---	---	---	10,676	59.3
	Military	7,561	---	---	---	13,551	75.3
F110-GE-100	Idle	1,111	---	---	---	592	3
	Approach	5,080	---	---	---	7,645	44
	Intermediate	7,332	---	---	---	11,595	66
	Military	11,358	---	---	---	17,460	100
	Afterburner	18,088	---	---	---	19,780	113
F117-PW-100	Idle	978	---	---	---	1,478	4
	Approach	4,645	---	---	---	13,088	31
	Intermediate	10,408	---	---	---	28,526	68
F118-GE-100	Idle	1,097	---	---	---	NA	NA
	Approach	3,773	---	---	---	NA	NA
	Intermediate	6,350	---	---	---	NA	NA
	Military	10,887	---	---	---	NA	NA

(con't)

Table 22. Engine Operation Summary (con't)

Engine Type	Operation Mode	Fuel flow, lbs/hr	Torque, Inch-Pounds	Shaft Horsepower	% Maximum Horsepower	Average Thrust, lbs	% Maximum Thrust
F404-GE-F1D2/400	Idle	685	---	---	---	632	6
	Approach	3,111	---	---	---	4,057	38
	Intermediate	6,464	---	---	---	8,305	79
	Military	7,739	---	---	---	9,608	91
	Afterburner	15,851	---	---	---	12,034	114
F110-GE-129	Idle	961	---	---	---	809	4
	Approach	4,832	---	---	---	8,034	45
	Intermediate	6,939	---	---	---	11,431	65
	Military	8,611	---	---	---	13,489	76
	Afterburner	15,564	---	---	---	17,467	99
F100-PW-100	Idle	1,067	---	---	---	1,174	8
	Approach	2,726	---	---	---	3,963	27
	Intermediate	7,549	---	---	---	10,992	75
	Military	9,211	---	---	---	12,827	87
	Afterburner	12,198	---	---	---	13,909	95
F100-PW-229	Idle	1,087	---	---	---	806	5
	Approach	3,098	---	---	---	3,768	21
	Intermediate	5,838	---	---	---	8,771	49
	Military	11,490	---	---	---	15,382	86
	Afterburner	20,793	---	---	---	18,218	102
T64-GE-100	Ground Idle	298	1,284	85	2	---	---
	75% Normal	941	6,564	1,458	34	---	---
	Normal	1,698	15,816	3,521	81	---	---
	Military	1,848	17,580	3,873	90	---	---
TF34-GE-100A	Idle	498	---	---	---	665	7
	Approach	933	---	---	---	2,550	28
	Intermediate	1,512	---	---	---	4,200	46
	Military	2,628	---	---	---	7,100	78

(a) Maximum horsepower not available for the auxilliary power units.
--- Blanks indicate a parameter which is not monitored during operation in the test cell.
NA - Thrust values were not available for this engine.